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Natural Resource Stewardship and Science

Wadeable Stream Habitat Monitoring at Chattahoochee River National Recreation Area

2017 Baseline Report

Natural Resource Report NPS/SECN/NRR—2019/2036



ON THE COVER

Picture looking upstream at the monitored reach on Long Island Creek (CHAT013) at Chattahoochee National Recreation Area on June 13, 2017. NPS photo / SECN

Wadeable Stream Habitat Monitoring at Chattahoochee River National Recreation Area

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Natural Resource Report NPS/SECN/NRR—2019/2036

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Summary and Key Findings

The Southeast Coast Network (SECN) stream habitat monitoring protocol collects data to give park resource managers insight into the status of and trends in stream and near-channel habitat conditions (McDonald et al. 2018a). Wadeable stream assessments are currently implemented at the five SECN inland parks with wadeable streams. These parks include Horseshoe Bend National Military Park, Kennesaw Mountain National Battlefield, Ocmulgee Mounds National Historical Park, Chattahoochee River National Recreation Area, and Congaree National Park. Streams chosen for assessment were specifically targeted for management interest (e.g., trail erosion issues and upstream urban development) or to provide a context for similar-sized stream(s) within the park or network (McDonald and Starkey 2018a).

The objectives of the SECN stream habitat monitoring protocol are to:

- Determine status of upstream watershed characteristics (basin morphology) and trends in land cover that may affect stream habitat;
- Determine the status of and trends in benthic and near-channel habitat in selected wadeable stream reaches (e.g., bed sediment, geomorphic channel units, and large woody debris; and
- Determine the status of and trends in cross-sectional morphology, longitudinal gradient, and sinuosity of selected wadeable stream reaches.

From June 8–16, 2017 data were collected at Chattahoochee National Recreation Area (CHAT) to characterize the in-stream and riparian habitat of 14 stream reaches (CHAT001–CHAT014). These data, along with geographic information system (GIS) analyses, are presented in this report to describe and compare the watershed-, reach-, and transect-scale characteristics of the surveyed reaches. The report is subdivided based on the Strahler stream order. This Summary (and Key Findings) section gives a general overview of the basin, habitat, and geomorphic characteristics of the surveyed streams as well as any management concerns. A bulleted list is provided for each reach to describe its distinguishing characteristics and/or management concerns.

Basin Characteristics

The watersheds draining to the surveyed stream reaches at Chattahoochee River NRA ranged from small mostly forested first-order watersheds to large mostly developed third-order watersheds. Based on the geomorphic and land cover characteristics of the watersheds, the majority of the watersheds (nine out of fourteen) likely have a flashy flow regime (three first-order, four second-order, and both third-order watersheds). The remaining five watersheds likely have less flashy flow regimes because they had lower slope/relief and/or low amounts of development. Gage data are needed to confirm these interpretations of each watershed's flow regime.

Habitat Characteristics

Based on bed sediment and geomorphic channel units (GCU), habitat within 10 of the reaches was classified as high energy (three first-order, five second-order, and two third-order streams). The habitat within the four remaining reaches was classified as low energy (two first-order and two second-order). Generally, when present, large woody debris (LWD) were important for step and pool

creation and thereby diversification of stream habitat. Given the high energy and flashy classification of many reaches, LWD serves to dissipate energy and trap fine organic material and sediment that would otherwise be transported downstream. Based on the GCUs, bed sediment, and LWD characteristics of the surveyed streams, instream habitat was classified as "good" for four streams (one first-order and three second-order), "fair" for seven streams (three first- order, two second-order, and two third-order), and "poor" for three streams (one first-order and two second-order). Overall, habitat classification for each reach may improve if: (1) there is an increase in stable (non-mobile) in-channel (non-bridging) LWD, (2) there is a reduction in the amount of fine sediment delivered to the reach, and/or (3) habitat (GCU) diversity increases. Conversely, habitat may degrade if: (1) LWD is transported out of the reach, (2) there is an increase in the amount of fine sediment added to and stored within the bed of the stream, and/or (3) habitat diversity decreases due to the previous two mechanisms.

Geomorphic Characteristics

All the reaches are recovering from a legacy of poor land use and responding to varying amounts of impervious surface cover in their watersheds. Six of the fourteen streams are (or will soon be) impacted by the headward migration of a downstream knickpoint (four first-order and two second-order streams). Where resistant bed material is lacking, knickpoints (defined as abrupt increases in stream slope) are often associated with stream bed incision. Bank undercutting and slumping was observed at all the streams at Chattahoochee River NRA. In the larger streams, slump blocks (e.g., the portions of bank that slumped in the channel) are usually eroded and the sediment is transported downstream. In the smaller streams, and lower energy portions of the larger streams, these slumps blocks can become sediment sinks if they become stabilized (i.e., by vegetation).

Management Concern

Out of the fourteen streams that were surveyed, two have immediate management concerns. Cabin Creek (CHAT012) and Long Island Creek (CHAT014) are eroding into a trail along the stream. Trail erosion at CHAT012 is a concern but will not be a great hazard to visitors once the trail fails (banks are relatively low). On the other hand, the bank at CHAT014 is fairly high (greater than 1.5 meters [4.9 feet {ft}]) and bank failure will create hazardous conditions along this section of trail. Erosion rates for both stream reaches have yet to be determined.

The following bullet points are intended to provide park managers with a brief description of each wadeable stream reach surveyed at Chattahoochee River NRA, during 2017, regarding: (1) watershed characteristics (i.e. land use land cover, slope, and relief); (2) in-stream habitat conditions (i.e. high versus low energy GCUs, bed material, prevalence of LWD); (3) how the habitat was classified (i.e. "good," "fair," or "poor") based on professional judgement of diversity of GCUs, LWD content, and bed material; and (4) general channel condition (i.e. bank conditions, degree of entrenchment, presence of knickpoints, or planform changes).

Headwater Streams (First Order)

CHAT002—"Undercut Creek"

- Steep and forested watershed
- High energy in-stream habitat, coarse bed material, and high volume of LWD
- Habitat classified as "good"
- Slumping banks and flood chute in floodplain
- Downstream knickpoint

CHAT003—"Steep Draw Creek"

- Steep and forested watershed
- Very high energy habitat (almost all riffle), coarse bed material, and an average number of LWD
- Habitat classified as "fair"
- Entrenched, some bank slumping
- Downstream knickpoint

CHAT006—"Three Mind Creek"

- Watershed has relatively low slope and relief and a high amount of development
- Majority of habitat is low energy pools, fine bed sediment, and low volume of LWD
- Habitat classified as "poor"
- A knickpoint has headcut into the reach and a LWD step is inhibiting headward migration

CHAT009—Fox Creek

- Watershed has relatively low slope and relief and is mostly forested
- Relatively low energy habitat (a lot of runs), bed sediment is relatively coarse, few LWD
- Habitat classified as "fair"
- Extensive undercutting, slumping, and high occurrence of bench and/or bar surfaces

CHAT012—Cabin Creek

- Steep and forested watershed
- Mixture of GCU, relatively fine bed sediment, low volume of LWD
- Habitat classified as "fair"
- Hiking trail is being undercut along the reach. Could be exacerbated by a knickpoint

Medium-Sized (Second Order) Streams

CHAT004—"Crayfish Creek"

- Steep and developed watershed
- Mixture of GCUs, coarse bed material, average amount of LWD
- Habitat classified as "good"
- Very entrenched but beginning to develop a meander planform inset within the higher surface

CHAT005—"Egg Creek"

- Steep and forested watershed
- Mixture of GCUs, relatively fine bed sediment, high amount of LWD
- Habitat classified as "fair"
- Headward migration of a knickpoint is being prevented by an LWD step

CHAT007—"Red Tail Creek"

- The watershed has low slope and relief and is covered by a mixture of forests, development, and pasture or grassland
- Habitat is very low energy, the bed sediment is very fine, and the reach is affected by the backwater effects of the Chattahoochee River
- Habitat classified as "poor"
- The stream is very entrenched with high hillslopes encroaching on the stream where lower slump surfaces are not protecting the hillslope

CHAT008—Mulberry Creek

- The watershed has average slope and relief and is mostly covered by development
- Mixture of GCUs, coarse bed sediment, and an average amount of LWD
- Habitat classified as "good"
- The stream has begun to develop a meandering planform inset within the higher terrace

CHAT010—"Beaver Creek"

- The watershed has average slope and relief and is mostly covered by development
- Mixture of long riffles and deep pools, coarse bed sediment, and high amount of LWD
- Habitat classified as "good"
- The stream has multiple inset surfaces within the higher-level terrace

CHAT011—Gunby Creek

- The watershed has average slope and relief and is mostly covered by development
- Mixture of riffles and pools, bed sediment is relatively coarse, no LWD

- Habitat classified as “fair” to “good”
- The reach is relatively straight but has a well-developed floodplain
- An incipient neck cut-off downstream may cause a knickpoint to migrate into the reach

CHAT014—Whitewater Creek

- The watershed has average slope and relief and is mostly covered by development
- Very low energy (mostly pools) habitat and the bed sediment is very fine
- Habitat classified as “poor”
- Downstream reduction in gradient (i.e., from culvert) may be causing the bed to aggrade
- The reach is influenced by slumping and has a relatively high degree of sinuosity

Large Low-Entrenchment (Third-Order) Streams

CHAT001—Haw Creek

- The watershed has average slope and relief and is mostly covered by development
- Mixture of GCUs, coarse bed sediment, and average amount of LWD
- Habitat classified as “fair” to “good”
- The reach is influenced by slumping and it is beginning to develop a meandering planform inset within the higher terrace surface

CHAT013—Long Island Creek

- The watershed has average slope and relief and is mostly covered by development
- Mixture of riffles, glides, and pools, fine bed sediment, and average amount of LWD
- Habitat classified as “fair” to “good”
- The reach is beginning to develop a meandering planform inset within the higher terrace
- The reach is actively eroding into a hiking trail on river right

List of Acronyms

ANOVA—Analysis of variance

B—Sand/gravel bar

Be—Bench

Bf—Bankfull

BM—Benchmark

Bo—Boulder

Br—Bedrock

BSi—Bank stability index

C—Cobble bar

CHAT—Chattahoochee National Recreation Area

Cl—Clay bar

CONG—Congaree National Park

CV—Coefficient of variation

DEM—Digital elevation model

FP—Floodplain

FPM—Floodplain margin

GCU—Geomorphic channel unit

GIS—Geographic information system

Gl—Glide

HOBE—Horseshoe Bend National Military Park

Is—Vegetated island

KEMO—Kennesaw Mountain National Battlefield Park

LWD—Large woody debris

LT—Low terrace

NED—National Elevation Dataset

NL—Natural levee

NLCD—National Land Cover Dataset

NPS—National Park Service

OCMU—Ocmulgee Mounds National Historical Park

P—Pool

R—Riffle

Ru—Run

SECN—Southeast Coast Inventory and Monitoring Network

Sl—Slump

SOP—Standard operating procedure

T#—Standard transect

Un—Undercut

Introduction

The Southeast Coast Network (SECN) Stream Habitat Monitoring Protocol collects data to provide park resource managers insight into the status of and trends in stream and near-channel habitat conditions (McDonald et al. 2018a). The data provided through this monitoring effort will provide park staff with information regarding the physical linkage between streams and park resources. Additionally, this monitoring program will provide early warnings of changing conditions that may negatively affect visitor experience and/or park infrastructure.

Wadeable stream monitoring is currently implemented at the five SECN inland parks with wadeable streams. These parks include Horseshoe Bend National Military Park (HOBE) in Alabama, Kennesaw Mountain National Battlefield (KEMO), Ocmulgee Mounds National Historical Park (OCMU), and Chattahoochee River National Recreation Area (CHAT) in Georgia, and Congaree National Park (CONG) in South Carolina. The streams at Horseshoe Bend NMP, Kennesaw Mountain NBP, and Chattahoochee River NRA are typical Appalachian Piedmont streams that are beginning to re-equilibrate to their modern flow and sediment regimes following the poor land use practices of the late 19th and early 20th centuries (McDonald and Starkey 2018a; McDonald and Starkey 2018b; McDonald 2019). The streams at Congaree National Park are typical low gradient, blackwater, Coastal Plain streams (McDonald and Starkey 2018c) while the streams at Ocmulgee Mounds NHP are a mixture of Appalachian Piedmont and Coastal Plain type streams (McDonald and Starkey 2018d). Streams chosen for monitoring were specifically targeted due to management interest (e.g., trail erosion issues and upstream urban development) or to provide a context for similar-sized streams in the park (see suitability reports for each park [cited in this paragraph] for more information).

The objectives of SECN stream habitat monitoring protocol are to:

- Determine status of upstream watershed characteristics, including basin area, basin slope, and drainage density, and trends in land cover that may affect stream habitat;
- Determine the status of and trends in the geomorphic dimensions of selected wadeable stream reaches, including cross-sectional morphology, bank characteristics (e.g., heights, angles, and vegetative cover), and reach slope and sinuosity; and
- Determine the status of and trends in physical measures of benthic and riparian habitat features present in selected wadeable stream reaches, including the size, type, and distribution of bed sediment and large woody debris (LWD), the distribution of geomorphic channel units (GCU), and canopy cover.

For this report, wadeable streams are narrowly defined as small- to medium-sized, perennially-flowing waterbodies, with easily identifiable channel banks, that can be accessed and traversed without the use of a watercraft. The wadeable streams referred to herein do not include some non-perennial channel-like features typical of a highly disturbed and gullied landscape.

This report presents the results of the wadeable stream surveys completed at Chattahoochee National Recreation Area (CHAT) during June 2017. The information provided in this report describes the

physical characteristics of the fourteen stream reaches that were surveyed. Additionally, this report provides a basin-scale context for the differences observed between the 14 streams. The results and discussion portions of this report are sub-divided based on Strahler stream order (first to third) to allow comparisons to be made between similar-sized streams. In addition to summarizing the individual results for each stream, the Implications and Synthesis of Results section of this report highlights the management implications for the data that were collected. A description of why each stream reach was chosen for monitoring can be found in McDonald and Starkey (2018b).

Study Area

The hydro-climatic conditions of the study area are characterized as humid subtropical with average annual rainfall around 50 inches per year (127 centimeters [cm] per year; Wright et al. 2011). Snowfall is negligible and winters are mild; summers are hot and humid. Average monthly temperature ranges from a low in December of approximately 27°F (-3°C) to a high in August of 92°F (33°C; Wright et al. 2011). Monthly rainfall totals are distributed rather evenly from October through May due to the influence of frontal systems that sweep through the region (Lecce 2000). Convective thunderstorms influence the region from late spring through early fall. While monthly precipitation tends to be high in the summer, the high levels of evapotranspiration attenuate streamflow during this part of the year (Lins 1997).

The natural condition of rivers draining the southeastern U.S. are generally characterized by meandering channels with densely vegetated banks (Leigh 2008). Contemporary river systems in the southeastern U.S. are in variously altered states that reflect multiple legacies of anthropogenic disturbance (James 2018). Beginning in the late 1800s, deforestation, increased row crop agriculture, and a general lack of soil conservation measures caused widespread erosion of topsoil from steeply sloped upland areas in the Appalachian Piedmont region (Trimble 1969). Sediment was transported to streams and floodplains, burying productive shoal and riffle habitats. Streams in the region were transformed, from the hard-bottomed, clear-flowing streams described by early land surveyors, into conduits of turbid water and sand. As row-crop agriculture became less dominant and forest cover increased, sediment delivery to streams was reduced and streambeds began to degrade (Schumm et al. 1984). Today, streambed elevations in many of the region's small streams have returned to historic or near historic levels though their geomorphic characteristics (width, depth, entrenchment) are quite different from early settlement conditions (Schoonover et al. 2007; Mukudan et al. 2011).

In addition to the legacy effects of agriculture, many Appalachian Piedmont streams (including those draining to and through Chattahoochee River NRA) have been further subjected to hydrologic alterations caused by urban/suburban development. Increases in impervious surface area associated with development creates conditions that increase the frequency and magnitude of peak discharges (Paul and Meyer 2001). Impervious surface area is also associated with lower-than-normal base flow during dry periods due to impaired groundwater recharge (Rose and Peters 2001). These flow alterations greatly influence available in- and near-stream habitats and can have a large impact on the biota found within a stream (Wenger et al. 2008).

As each stream recovers from its unique history of land use and equilibrates to its current flow and sediment regime it will pass through a series of semi-predicable stages of evolution (James 2018).

These stages include aggradation (receiving more sediment than flow regime can transport), degradation and narrowing (caused by a reduction in sediment and/or increased runoff), further degradation and widening, and finally stabilization and more natural reworking of in-channel alluvium (Figure 1). The exact stage that each stream is currently at is dependent on the location of the stream within its network and the unique history and current land use/land cover conditions of the stream's watershed. In general, streams in the Appalachian Piedmont are at the third stage of channel development (further degradation and widening) and their banks are quite unstable and subject to undercutting and slumping.

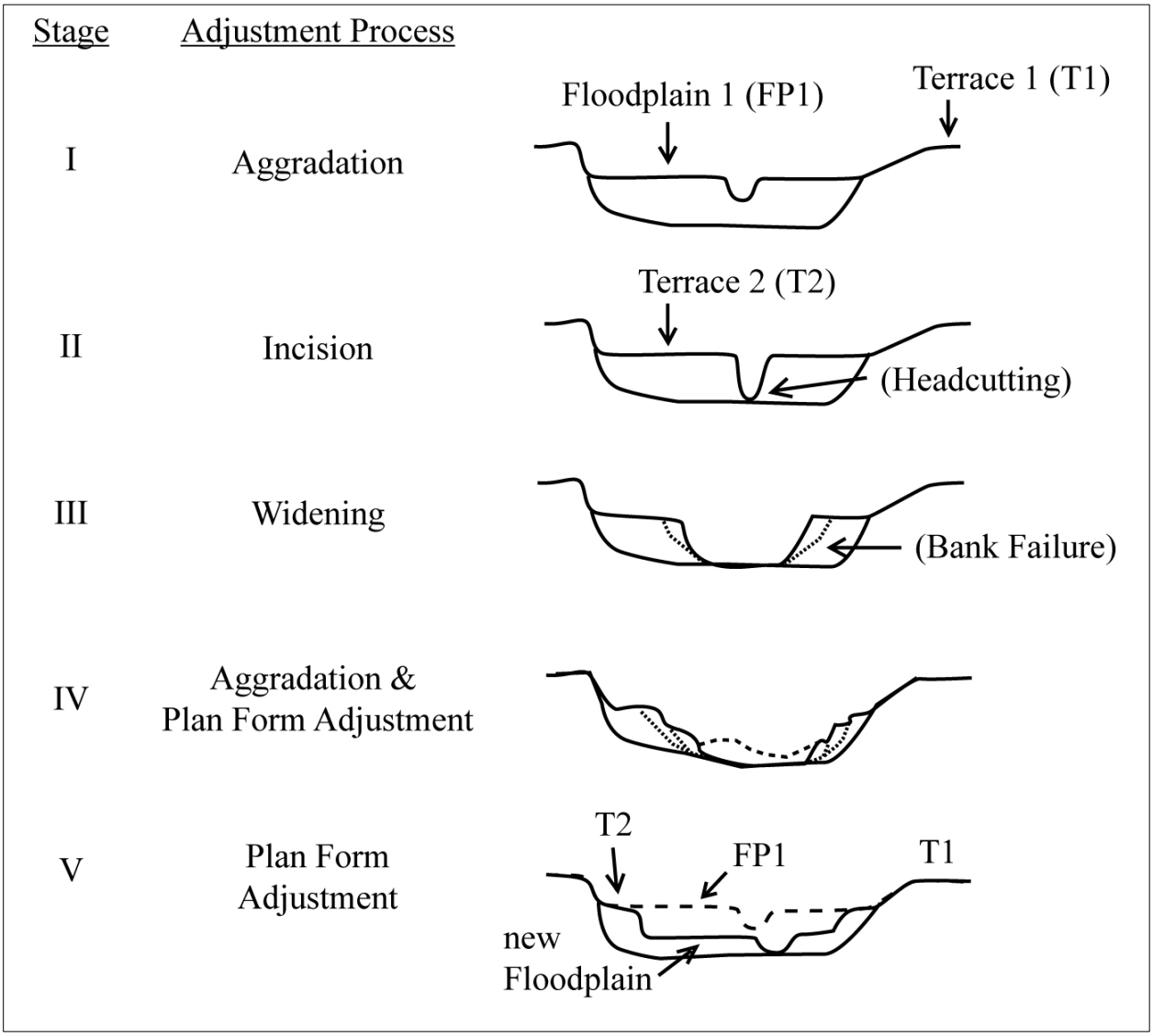


Figure 1. Generalized channel evolution model (modified from Schumm et al. 1984).

Chattahoochee National Recreation Area (CHAT)

The Chattahoochee River NRA covers 6,800 acres (2,752 hectares [ha]) of mixed pine/hardwood forests and wetlands buffering 48 miles (77.2 kilometers [km]) of the Chattahoochee River (Figure 2). The park consists of 16 non-contiguous management units stretching from Buford Dam to north Atlanta, Georgia, the Southeast's largest metropolitan area (U.S. Census Bureau 2010). The Chattahoochee River is utilized for recreation, power generation, as a water supply, and for waste-water assimilation for the greater metropolitan Atlanta area. This section of the Chattahoochee River is highly regulated by flows from Buford Dam, which was completed in 1957. Chattahoochee River NRA offers green space and water-based recreational opportunities for the Atlanta metropolitan area and was designated as America's first official National Water Trail in 2012.

The Upper Chattahoochee River's position in a relatively stable fault zone has resulted in a long and narrow watershed (Burkholder et al. 2010). Many small tributaries feed the mainstem along the Chattahoochee River NRA-authorized area. Flow alteration associated with the impoundment and release of water for power generation has a pronounced effect on the flow patterns of the Chattahoochee River and its tributaries. The majority of the tributaries flowing through CHAT management units are small, lower-order (first- to third-order) streams that are heavily impacted by the direct and indirect effects of urbanization. Changes in the watersheds outside and upstream of the park have led to higher peak flows and lower base flow in the streams that run through the park (Gregory et al. 2012; Starkey 2015). These altered stormflow regimes potentially threaten park infrastructure (e.g., parking lots, bridges, and trails) due to increased channel instability. Stormwater discharges from the urban areas that feed into park streams also impact water quality by increasing the temperature, turbidity, and bacterial and heavy metal loads. Stream habitat and water quality are also influenced by utility right of ways that commonly cross both the wadeable and non-wadeable streams in the park. Within the park, stream bank conditions are often impacted by visitors using bicycle and foot trails.

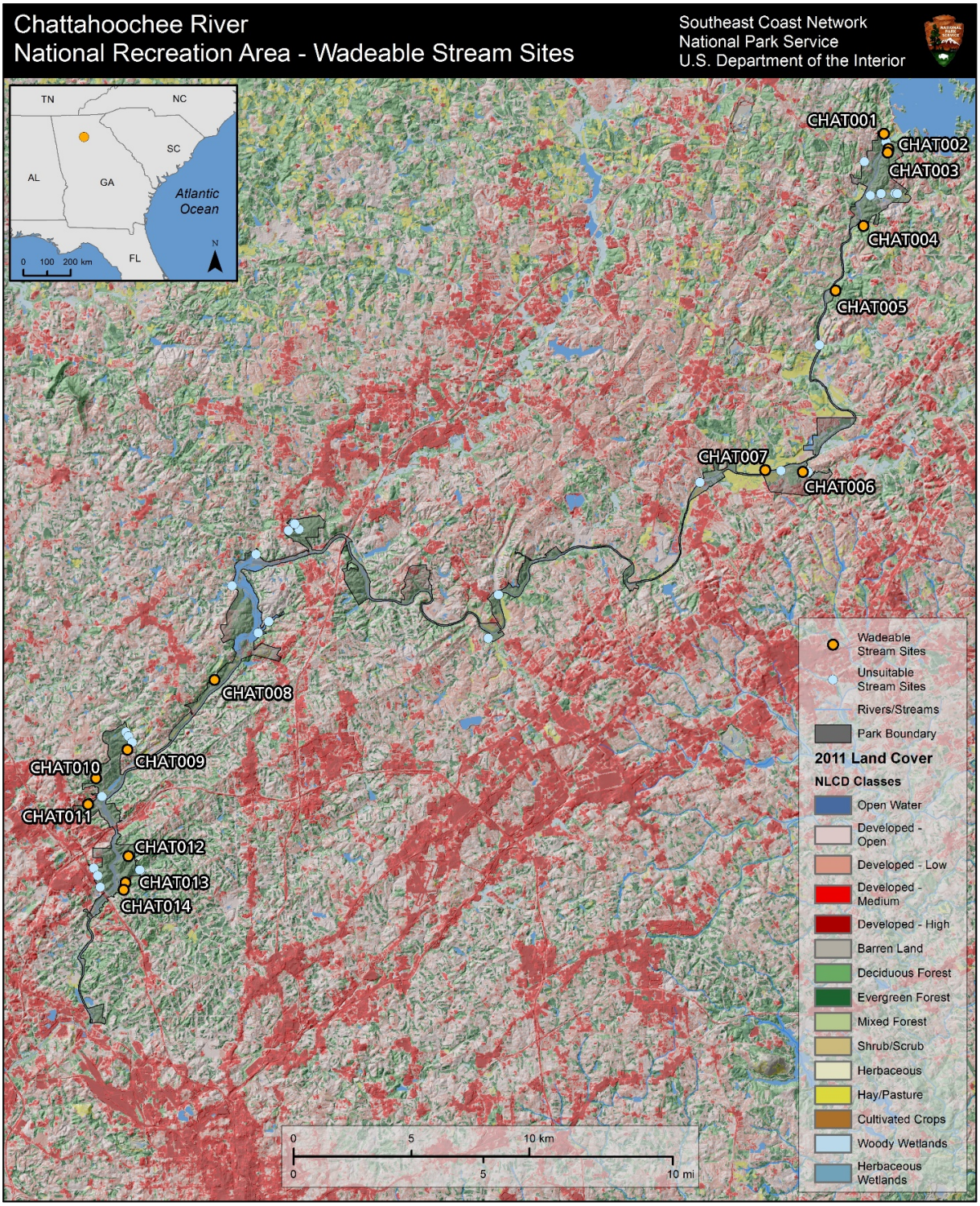


Figure 2. Map showing Chattahoochee National Recreation Area and its wadeable stream reaches (CHAT001–CHAT014). Wadeable stream segments that were deemed unsuitable for monitoring are also shown (McDonald and Starkey 2018b). Land use/land cover (NLCD 2011 dataset; Homer et al. 2015) and perennial streams (derived from a 10 meter [32.8 ft] digital elevation model; data available from the U.S. Geological Survey) in the vicinity of the park are also shown. See McDonald and Starkey (2018b) for explanations of site selection.

Methods

The habitat characteristics and geomorphic parameters that were selected for monitoring are based on those collected by other federal organizations (USGS, Fitzpatrick et al., 1998; EPA, Hughes 2000; and USFS, Harrelson et al., 1994). The physical structure of in- and near-stream habitat has a strong influence on the biological communities and overall ecological integrity of lotic ecosystems (Newson and Newson 2000). Monitoring stream habitat not only provides an understanding of the physical suitability for aquatic species but can also identify stressors that could degrade other park resources and negatively affect visitor experiences.

The data collected as part of the SECN wadeable stream monitoring protocol are divided into three scales of analysis: (1) basin-scale characteristics; (2) reach-scale measurements, along and between eleven standard transects per reach; and (3) detailed cross-sectional measurements, at three of the eleven transects per reach (Figure 3). A table containing a list and definitions of each variable collected under the protocol can be found in Appendix A.

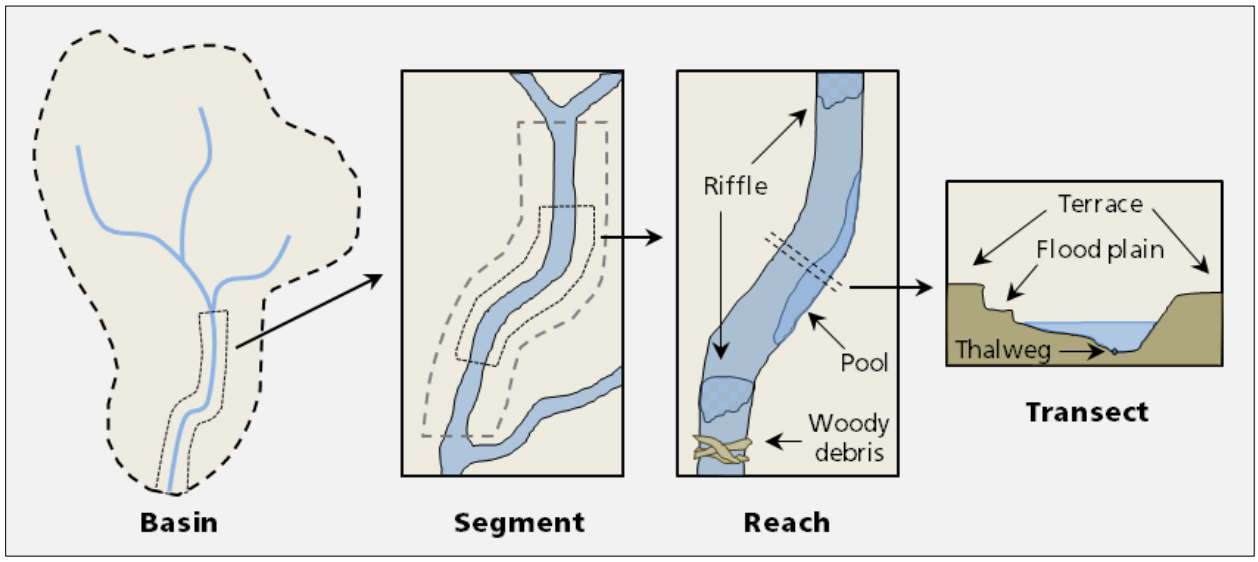


Figure 3. Spatial hierarchy of stream systems and scales of data collection (modified from Fitzpatrick et al. 1998).

While summarized in this document, a list of standard operating procedures and an overview of the methods used to collect and process the survey data are available in McDonald et al. (2018a).

Basin Characteristics

Understanding the physical characteristics of a drainage basin as well as the land use and land cover upstream of a reach is critical to understanding changes to and differences between streams. The parameters collected for this protocol describe how dissected the watershed is (drainage density; Knighton 1998), the magnitude and duration of floods (basin shape; Gregory and Walling 1973), the rainfall-runoff potential of a watershed (average watershed slope; Hewlett and Hibbert 1967), potential sediment yield (basin relief ratio; Strahler 1957), and the amount of energy available to

move sediment through a stream network (entire stream gradient; Craig and Rankl 1978; Fitzpatrick et al. 1998). A description of these basin characteristics can be found in McDonald et al. (2018a).

Basin-scale measures are calculated after permanent sites have been determined. These measurements and analyses are conducted within a GIS using digital elevation models (DEMs) from the National Elevation Dataset (NED) and land cover data from the National Land Cover Database (NLCD). Instructions for the GIS basin analysis can be found in SOP 1.2.15 *Stream Habitat Assessment Basin and Segment Scale Data Summary—Version 1.0* (McDonald et al. 2018b).

Reach-Scale Measurements

The reach-scale characteristics of each monitored reach are measured at and between 11 equidistant transects (distance between transects is two times average wetted width; Figure 4). Reach length is 20 times average wetted width (as determined during the initial survey of the reach). Data collected at each of these transects include: vegetative bank cover, presence of eroding banks, bed and bank material, channel widths (e.g., wetted, active, bankfull, and channel-full widths), water depth, and bank heights/angles. In addition to a qualitative description of bed sediment at each transect, a quantitative measure of bed sediment is obtained by conducting a Wolman pebble count on a representative riffle within the reach (Wolman 1954).

These data provide an understanding of the geomorphic or physical characteristics of the survey reach and are used to derive a bank stability score for the reach (Table 1). Many stream banks in the Appalachian Piedmont are scored as “at-risk” or “unstable.” This condition is consistent with expectations, given that many comparable streams in the region are currently reestablishing functional floodplains within their highly entrenched channel systems.

To understand in-stream and near-channel habitats, measurements are also taken between each transect. These between transect measurements include: canopy cover, the amount and type of in-stream habitat (e.g., high-energy riffles vs. low-energy pools), an inventory of large woody debris (LWD; defined as greater than 1 meter [3.3 ft] in length and greater than 10 centimeters [3.9 in] in diameter as defined in McDonald et al. 2018a), and a description of in-channel features (e.g., sand / cobble bars).

Using these measures of in-stream habitat, each stream’s habitat is classified as ‘poor,’ ‘poor-to-fair,’ ‘fair’, ‘fair-to-good,’ or ‘good.’ These classifications are a generalized interpretation of in-stream habitat and additional work is needed to determine how flow (e.g., flashiness of flow and baseflow conditions), water quality, and in-stream physical characteristics affect biodiversity and stream health on each reach. In addition to classifying each stream’s habitat, processes or events are identified that may affect these classifications; either leading to habitat improvement or degradation.

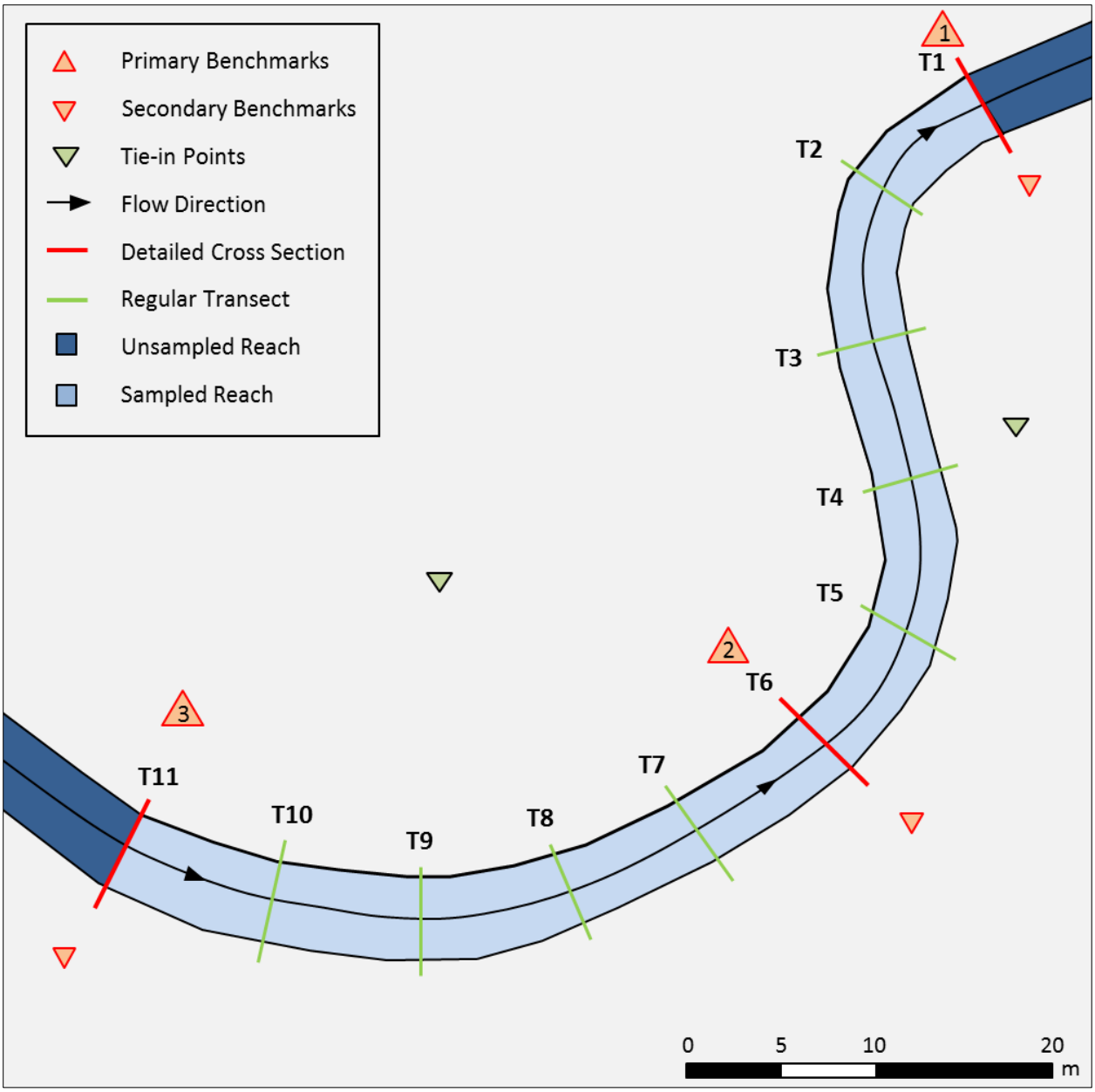


Figure 4. Example layout of stream reach with benchmarks, tie-in points, and transects.

Table 1. Bank Stability Index (BSi) from Fitzpatrick et al. (1998). A BSi score is determined by adding up the bank angle, vegetative cover, bank height, and bank sediment scores for each bank (separate score for left and right banks at each transect)[1] [m—meters].

Bank Stability Factor	Classification	Score
Angle (°)	0–30	1
	31–60	2
	> 60	3
Vegetative cover (%)	> 80	1
	50–80	2
	20–49	3
	< 20	4
Bank Height (m)	<1	1
	1–2	2
	2–3	3
	3–4	4
	> 4	5
Type of Bank Sediment	Bedrock, artificial	1
	Boulder, cobble	3
	Clay	4
	Silt	5
	Sand	8
	Gravel/Sand	10

[1] Total score rankings: 4-7 stable; 8-10 at-risk; 11-15 unstable; and 16-22 very unstable.

Detailed Transect Cross-Sections

Three of the eleven standard transects (optimally T1, T6, and T11) are surveyed using a survey grade (sub-millimeter accuracy) total station. These surveys allow lateral variability along each transect to be quantified and in- and out-of-channel changes to be monitored through time (Figure 5). Additionally, repeated surveying of channel cross-sections allows changes in streambed elevation and bank profiles to be quantitatively assessed in relation to a known point (benchmark). These data will be used to calculate bankfull and channel-full areas and will be used along with the bank stability index to assess the condition and stability of the reach.

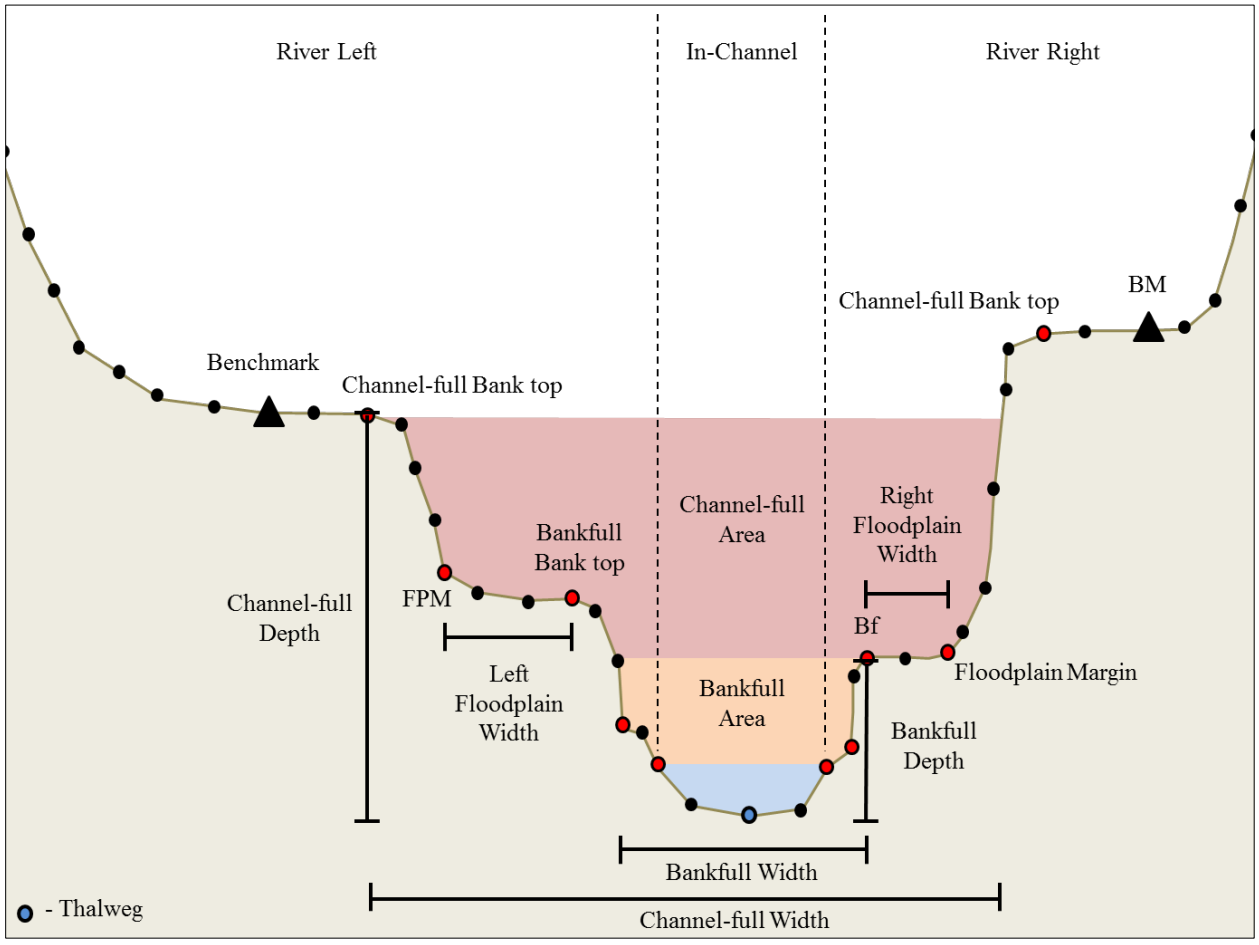


Figure 5. Hypothetical detailed transect cross-sectional survey showing the diagnostic geomorphic surfaces that should be surveyed and the descriptive characteristics that will be derived from the data. Bankfull area includes baseflow area (light blue) and bankfull area (orange). Channel-full area includes baseflow, bankfull, and channel-full (red) areas.

Statistical Analysis

The statistical significance of the difference between paired sites for nine variables was tested using two-sample t-tests. These nine variables included:

1. pebble count data (millimeters);
2. thalweg depth (meters);
3. thalweg position (% distance from left bank);
4. wetted width (meters);
5. active channel width (meters);
6. channel-full width (meters);
7. channel-full height (meters);
8. bank angle (°); and
9. vegetative cover of the banks (%).

Bankfull width is not included in the statistical analysis because bankfull was not measured on each transect (due to lack of floodplain) and the number of bankfull measurements at each reach was not equal.

It was expected that all the surveyed streams are to some degree "disturbed." The pairings were not chosen to compare a relatively undisturbed reference stream to a disturbed stream. The pairs were chosen to determine how similar sized streams are changing to determine how the small differences in basin morphology and land cover coupled with segment- and reach-scale differences will influence the long-term development of these streams. Paired sites are identified in Table 2 and the reason for their pairing is briefly described in the Results section. A detailed explanation of the reason for the pairings can be found in McDonald and Starkey (2018b).

In addition to the difference between pairs tests, a one-way analysis of variance (ANOVA) test was conducted to determine if there are significant differences in the nine previously mention variables among streams of similar order. If the ANOVA showed a significant difference, a post hoc Tukey test was used to determine where the difference occurred (i.e. which reach(es) differed significantly from the other reach(es) of the same stream order).

Table 2. Wadeable stream monitoring sites at Chattahoochee River National Recreation Area. A detailed description of each reach can be found in McDonald and Starkey (2018b).

Site Number	Park Unit	Stream Name	Lat	Long	Stream Type	Strahler Stream Order	Pairs
CHAT001	Bowman Island	Haw Creek	34.158	-84.080	Large-Low Entrenchment	3	1
CHAT002	Bowman Island	"Undercut Creek"	34.153	-84.078	Small-Headwater	1	2
CHAT003	Bowman Island	"Steep Draw Creek"	34.151	-84.079	Small-Headwater	1	2
CHAT004	Ors Ferry	"Crayfish Creek"	34.123	-84.092	Medium-Low Entrenchment	2	3
CHAT005	Settles Bridge	"Egg Creek"	34.099	-84.105	Medium-Low Entrenchment	2	3
CHAT006	Suwanee Creek	"Three Mind Creek"	34.029	-84.124	Small-Headwater	1	–
CHAT007	Rogers Bridge	"Red Tail Creek"	34.032	-84.139	Medium-High Entrenchment	2	–
CHAT008	Johnson Ferry	Mulberry Creek	33.957	-84.395	Medium-Low Entrenchment	2	4
CHAT009	Cochran Shoals	Fox Creek	33.931	-84.436	Small-Headwater	1	5
CHAT010	Cochran Shoals	"Beaver Creek"	33.921	-84.450	Medium-Low Entrenchment	2	4
CHAT011	Cochran Shoals	Gunby Creek	33.911	-84.452	Medium-Low Entrenchment	2	6
CHAT012	Palisades	Cabin Creek	33.890	-84.436	Small-Headwater	1	5
CHAT013	Palisades	Long Island Creek	33.884	-84.433	Large-Low Entrenchment	3	1
CHAT014	Palisades	White Water Creek	33.877	-84.440	Medium-Low Entrenchment	2	6

Results

During June 8–16, 2017, 14 streams were surveyed at Chattahoochee River National Recreation Area following the methods outlined in SOP 1.2.16 *Wadeable Stream Reach-Scale Field Data Collection–Version 1.0* (McDonald et al. 2018c), and SOP 1.2.18 *Using a Total Station to Conduct a Stream Survey–Version 1.0* (McDonald et al. 2018d). Streams were selected to be representative of similar-sized streams (i.e., first-, second-, and third-order streams) in the park (Table 2). Of the fourteen streams, five were classified as small-headwater streams (first order), six were classified as medium-low entrenchment streams (second order), one was classified as medium-high entrenchment (second order), and two were classified as large-low entrenchment (third order). To compare similar sized streams, Strahler stream order is used to subdivide the results. Field surveys, in-office analyses, and statistical comparisons between the monitored reaches are presented in the following sections. Results and data summary tables for each reach are provided in Appendices B–O.

Headwater Streams (First Order)

Reach Descriptions

CHAT002—"Undercut Creek"

On June 15, 2017, stream survey data were collected at CHAT002. CHAT002 is located along an unnamed first-order stream nicknamed "Undercut Creek" because of the extensive and deep undercuts observed during the initial assessment of the stream segment. The monitored reach on "Undercut Creek" is approximately 181 meters (594 ft) upstream of its confluence with the Chattahoochee River. CHAT002 can be accessed by following the social trail along the river left side of the Chattahoochee River and then following the creek upstream to the monitored reach. Large tree falls have had a significant influence on the stream and a natural levee and flood chute have developed upstream of one of these tree falls (Figure 6).

CHAT002's channel has a low degree of entrenchment and there are signs of overbank flows (e.g., flow paths through the floodplain and down-valley oriented debris trails). Eight undercuts were measured within the reach, including one large undercut (0.68 meters [2.23 ft] deep) between T5 and T6. The reach that was surveyed was 30 meters (98.4 ft) long with 3 meters (9.8 ft) between transects. CHAT002 is paired with CHAT003 because they are in close proximity (share a watershed divide), have similar sized watersheds (0.32 square kilometers [0.12 square miles {sq mi}; CHAT002] and 0.51 square kilometers [0.20 sq mi; CHAT003]; Table 3), and similar land use/land cover (mostly forested with some development, Table 4). Water surface slope (longitudinal profile) for this section of "Undercut Creek" was 0.0341 m/m (Table 5). The longitudinal profile was relatively consistent with only one section with higher slope (above T6; Figure 7). The detailed transects were surveyed on T2 (BM1), T6 (BM2), and T10 (BM3). Detailed transect 1 (T2) and 2 (T6) have developed small floodplains on rivers right and left, respectively (Figure 8). The flood chute, running along the river left out-of-channel area was surveyed on both detailed transects 2 (T6) and 3 (T10; Figure 8). Survey results for CHAT002 can be found in Appendix B.

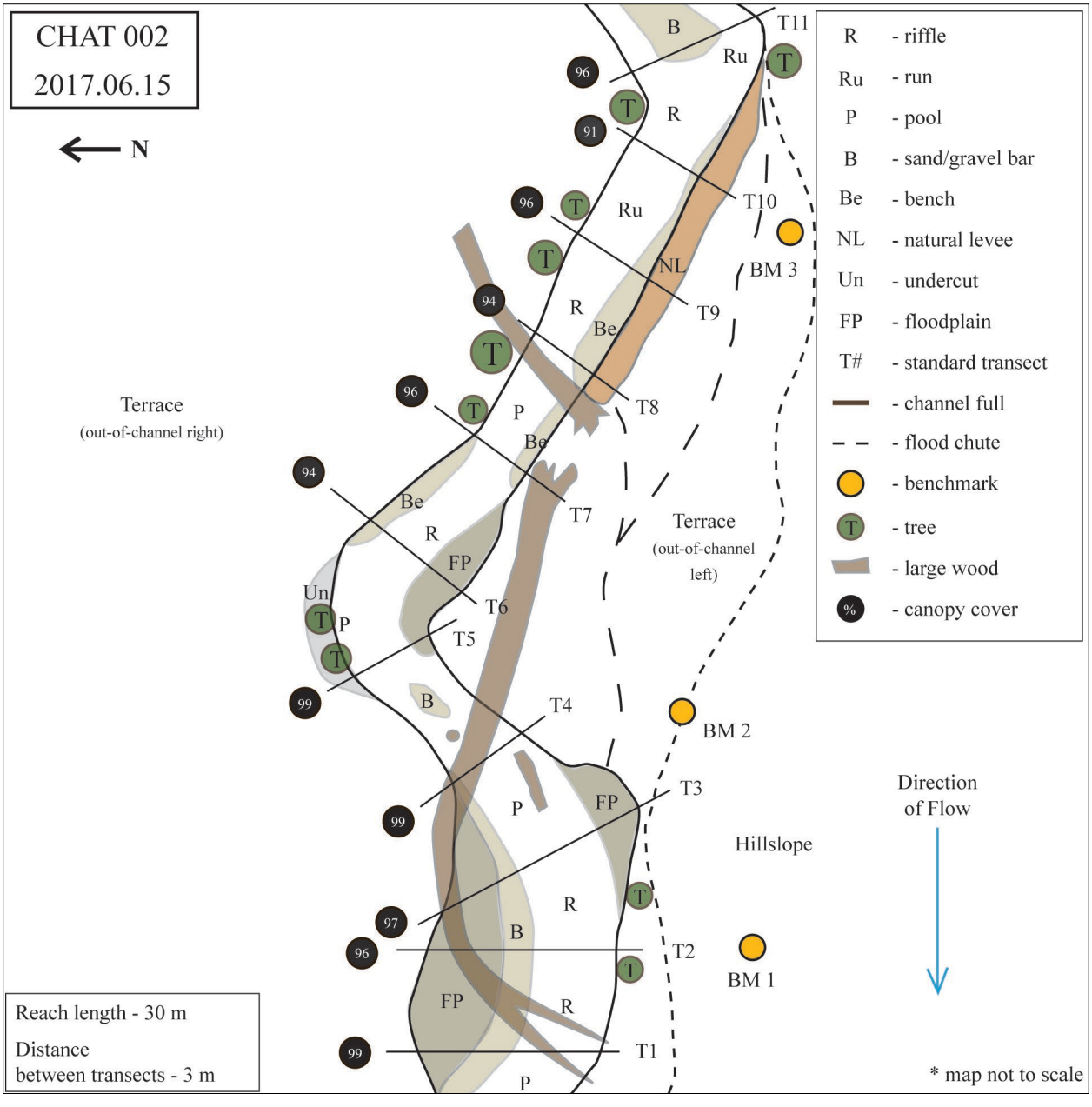


Figure 6. Reach-scale map of CHAT002. Important geomorphic surfaces and in-channel features are labeled to provide a context for the standard and detailed transect information provided in this report. The canopy cover circles are varying shades of grey which indicate the amount of canopy cover at each transect (high and low coverages are labeled).

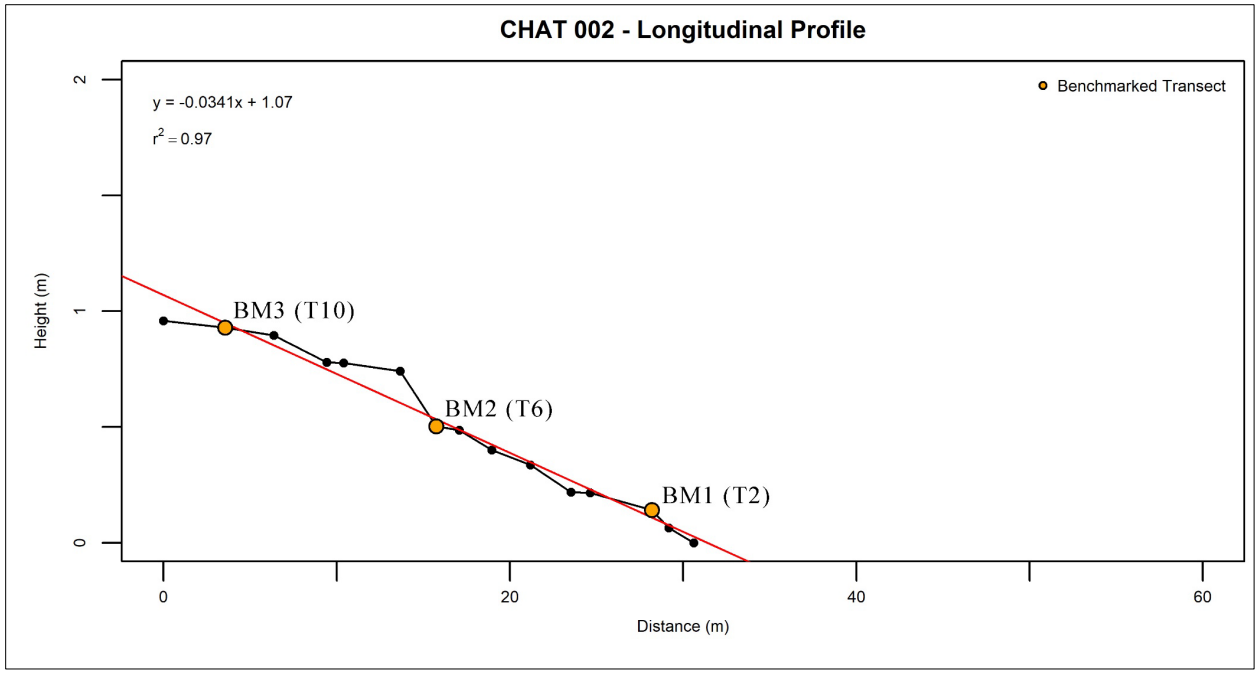


Figure 7. Longitudinal profile for CHAT002. The red line on the graph corresponds to the interpreted slope of the reach. The r^2 value describes the strength of the trend line. The 'T#' in parentheses indicates the standard transect number on which the detailed transects were surveyed.

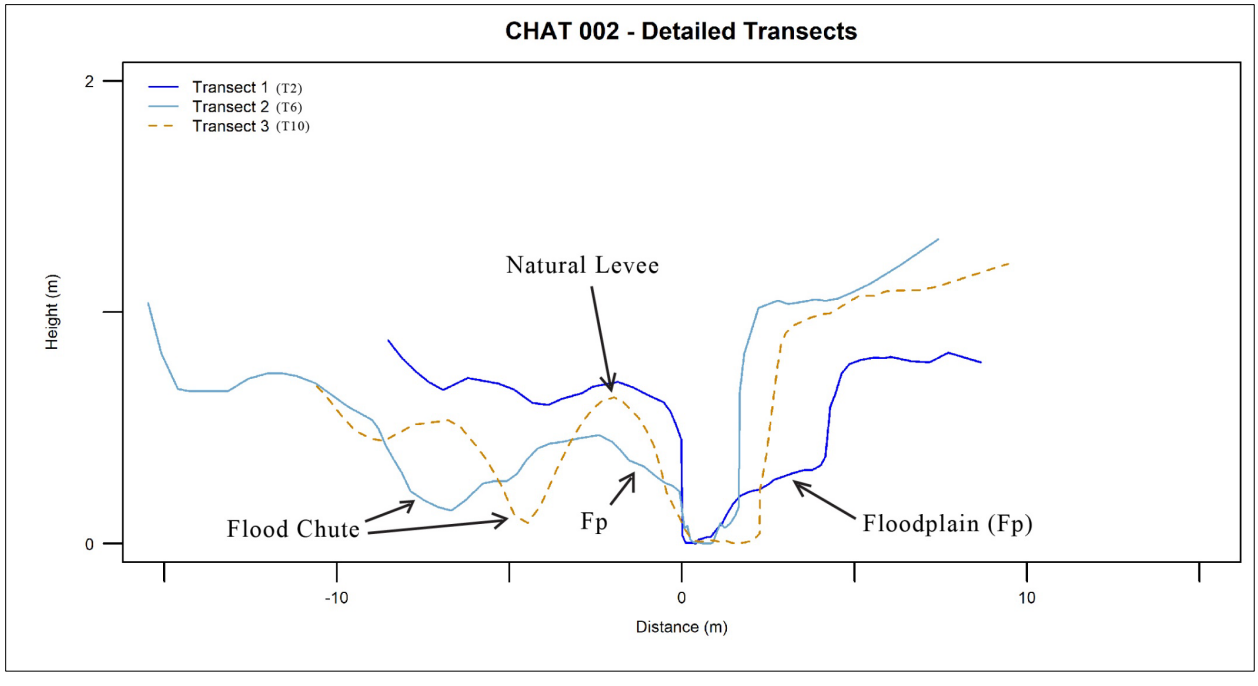


Figure 8. Comparison of the detailed transects at CHAT002. The location of the left channel-full points for each transect are normalized to allow for comparisons between transects. The 'T#' in parentheses indicates the standard transect number on which the detailed transects were surveyed.

Table 3. Watershed characteristics for the first-order streams at Chattahoochee River NRA calculated using the National Elevation Dataset (NED) 10-meter digital elevation model [km—kilometers; m—meters; SD—Standard deviation; CV—Coefficient of variation].

Basin Characteristic	CHAT002	CHAT003	CHAT006	CHAT009	CHAT012
Drainage Area (km^2)	0.32	0.51	0.20	0.51	0.30
NPS Managed Area (km^2)	0.17	0.35	0.09	0.42	0.10
NPS Managed Area (%)	54%	69%	45%	83%	34%
Total Stream Length (km)	0.52	0.67	0.11	0.62	0.10
Drainage Density	1.64	1.32	0.55	1.22	0.35
Strahler Order	1	1	1	1	1
Bifurcation Ratio	1.00	1.00	1.00	1.00	1.00
Entire Stream Gradient	0.0616	0.0531	0.0537	0.0457	0.0459
Segment Gradient	0.0840	0.0385	0.0186	0.0204	0.0378
Slope - Average	9.78	11.02	8.36	8.65	11.87
Slope - SD	5.55	5.92	4.78	5.21	5.37
Slope - CV	0.57	0.54	0.57	0.60	0.45
Basin Length (km)	1.36	1.30	1.04	1.41	1.00
Basin Shape	0.17	0.30	0.18	0.26	0.29
Basin Relief (m)	84.52	85.15	55.00	60.36	73.01
Basin Relief Ratio	0.062	0.066	0.053	0.043	0.073
Elevation - SD (m)	17.23	16.64	12.00	13.55	12.57

Table 4. Land use/land cover characteristics from 2011 for the first-order streams at Chattahoochee River NRA (NLCD, Homer et al. 2015).

NLCD Classes	CHAT002	CHAT003	CHAT006	CHAT009	CHAT012
Developed Open & Low (%)	18	9	46	22	23
Developed Med. & High (%)	0	5	16	0	0
Forested (%)	80	86	37	75	77
Grassland (%)	2	0	0	0	0
Cultivated (%)	0	0	0	0	0

Table 5. Summary of the results of the detailed transect surveys. Slope and sinuosity measures are based on the water surface and change in slope points taken within the reach. The bankfull and channel-full values are averages of the three detailed transect surveys [m—meters].

Site Number	n[1]	Slope	Sinuosity	n[2]	Bankfull Area (m^2)	Bankfull Width (m)	Bankfull Depth (m)	Channel-full Area (m^2)	Channel-full Width (m)	Channel-full Depth (m)
CHAT002	15	-0.0341	1.36	3	0.20	1.94	0.15	2.13	6.72	0.59
CHAT003	15	-0.0313	1.12	3	0.43	2.11	0.24	3.40	6.47	1.06
CHAT006	16	-0.0236	1.11	3	0.54	2.28	0.39	2.29	10.43	0.61
CHAT009	13	-0.0144	1.12	3	1.05	3.00	0.50	2.30	4.49	0.82
CHAT012	13	-0.0234	1.44	3	0.47	2.15	0.32	1.01	3.36	0.51

[1] Number of measurements for slope.

[2] Number of measurements for bankfull and channel-full area, width, and depth.

CHAT003—"Steep Draw Creek"

On June 15, 2017, stream survey data were collected at CHAT003. CHAT003 is located along an unnamed first-order stream that was nicknamed "Steep Draw Creek" because of the steep trek into the site that was encountered during the initial assessment of the stream segment. The monitored reach on "Steep Draw Creek" is approximately 160 meters (525 ft) upstream from its confluence with the Chattahoochee River. CHAT003 can be accessed by following the social trail along the river left side of the Chattahoochee River, crossing "Undercut Creek" and continuing over the watershed divide.

One large tree fall is influencing the upstream transects (Figure 9). Additionally, an ephemeral drainage on river right, near T6, is also influencing the reach. CHAT003's channel is entrenched except for one area, between T1 and T2, that has developed a small floodplain and a few low benches or high side bars, that are approximately at bankfull height, on T2 (river left) and between T4 and T5. The reach surveyed was 50 meters (164 ft) long with 5 meters (16.4 ft) between transects. As mentioned in CHAT002's reach description, CHAT003 is paired with CHAT002 because of proximity and similarity of watershed size and land cover (Tables 3 and 4). Water surface slope (longitudinal profile) for this section of "Steep Draw Creek" was 0.0313 m/m (Table 5). The longitudinal profile is relatively consistent with only one section with higher slope (between T8 and T9; Figure 10). The detailed transects were surveyed on T1 (BM1), T6 (BM2), and T11 (BM3). Detailed transect 1 (T1) had a small floodplain area on river right while the other two transects (T6 and T11) were entrenched and had no floodplain development (Figure 11). Survey results for CHAT003 can be found in Appendix C.

CHAT006—"Three Mind Creek"

On June 16, 2017, stream survey data were collected at CHAT006. CHAT006 is located along an unnamed first-order stream nicknamed "Three Mind Creek" because three distinctive sections were observed during the initial survey (highly entrenched upstream, low banks and wide floodplain in the middle, and becoming increasingly entrenched downstream). The monitored reach on "Three Mind Creek" is positioned on the transition from the middle not entrenched section to the increasingly entrenched downstream section (Figure 12). CHAT006 is approximately 325 meters (1,066 ft) upstream of its confluence with Suwanee Creek. CHAT006 can be accessed by following the trail at the end of Chattahoochee Drive down to within 50 meters (164 ft) of the stream.

The most distinguishing characteristic of "Three Mind Creek" is the large change in slope (knickpoint) above T3 and the transition to an entrenched channel below this change in slope. The reach that was surveyed was 20 meters (65.6 ft) long with 2 meters (6.6 ft) between transects. CHAT006 was not specifically paired with any of the other sites; though it is included in the ANOVA and post-hoc Tukey tests to determine whether it is significantly different than the other first-order streams. Water surface slope (longitudinal profile) for this section of "Three Mind Creek" was 0.0236 m/m (Table 5). The longitudinal profile is fairly flat upstream of the knickpoint between T3 and T4 (Figure 13). Detailed transects were surveyed on T1 (BM1), T6 (BM2), and T11 (BM3). Detailed transects 2 (T6) and 3 (T11) had well developed floodplains on both sides of the stream (Figure 14). Detailed transect 1 (T1), which is below the knickpoint, was entrenched and the channel now likely has little to no connection to its out-of-channel area. Survey results for CHAT006 can be found in Appendix D.

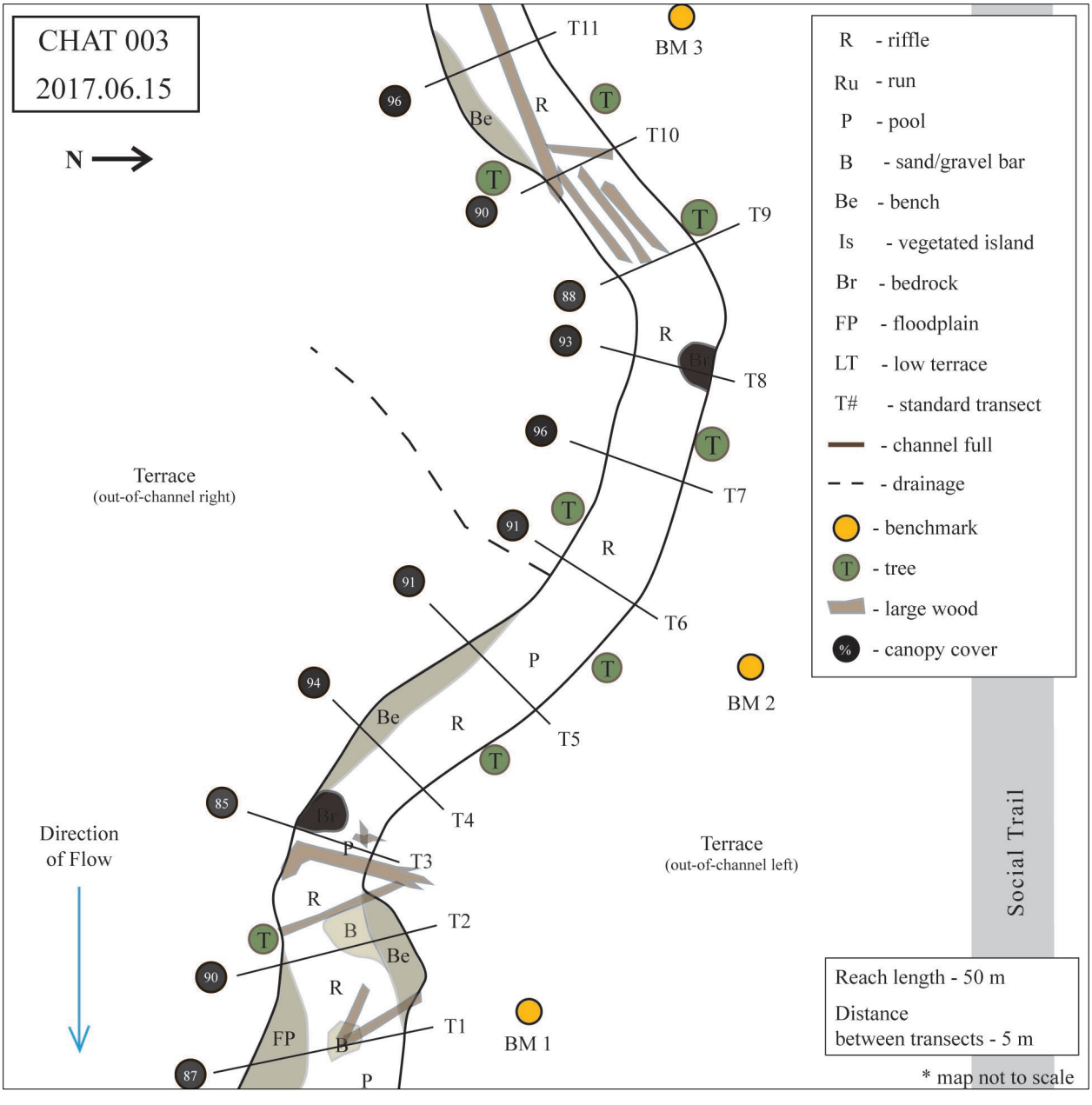


Figure 9. Reach-scale map of CHAT003. Important geomorphic surfaces and in-channel features are labeled to provide a context for the standard and detailed transect information provided in this report. The canopy cover circles are varying shades of grey which indicate the amount of canopy cover at each transect (high and low coverages are labeled).

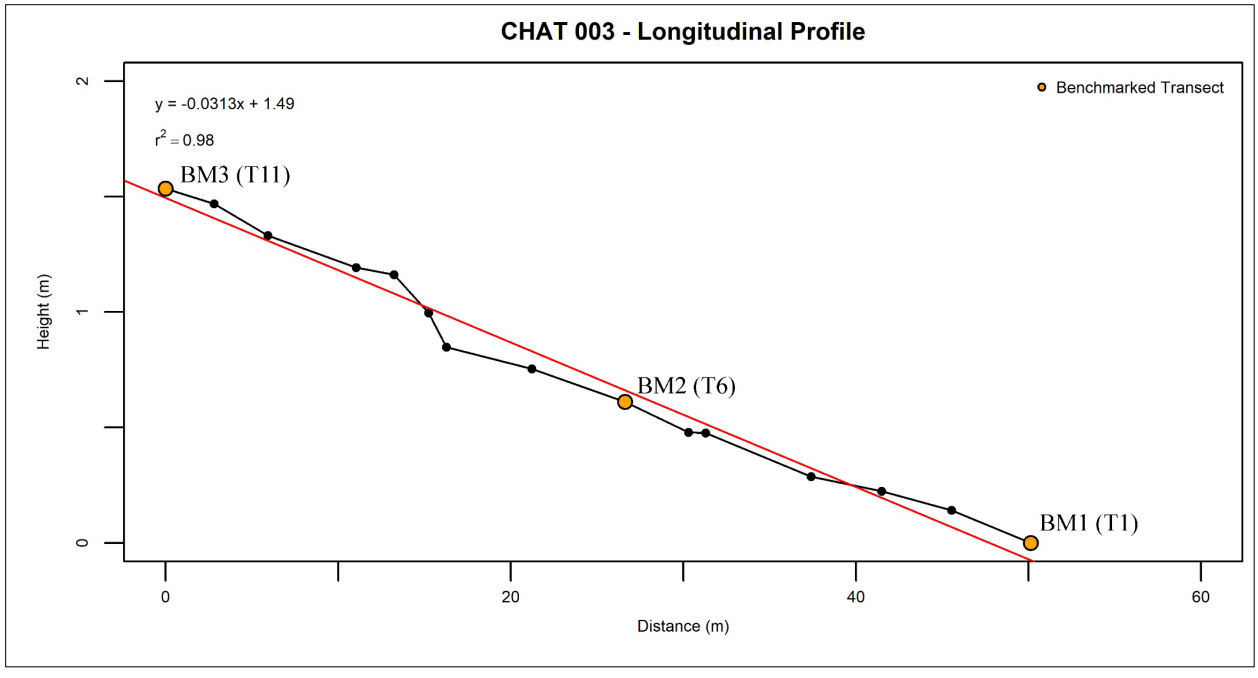


Figure 10. Longitudinal profile for CHAT003. The red line on the graph corresponds to the interpreted slope of the reach. The r^2 value describes the strength of the trend line.

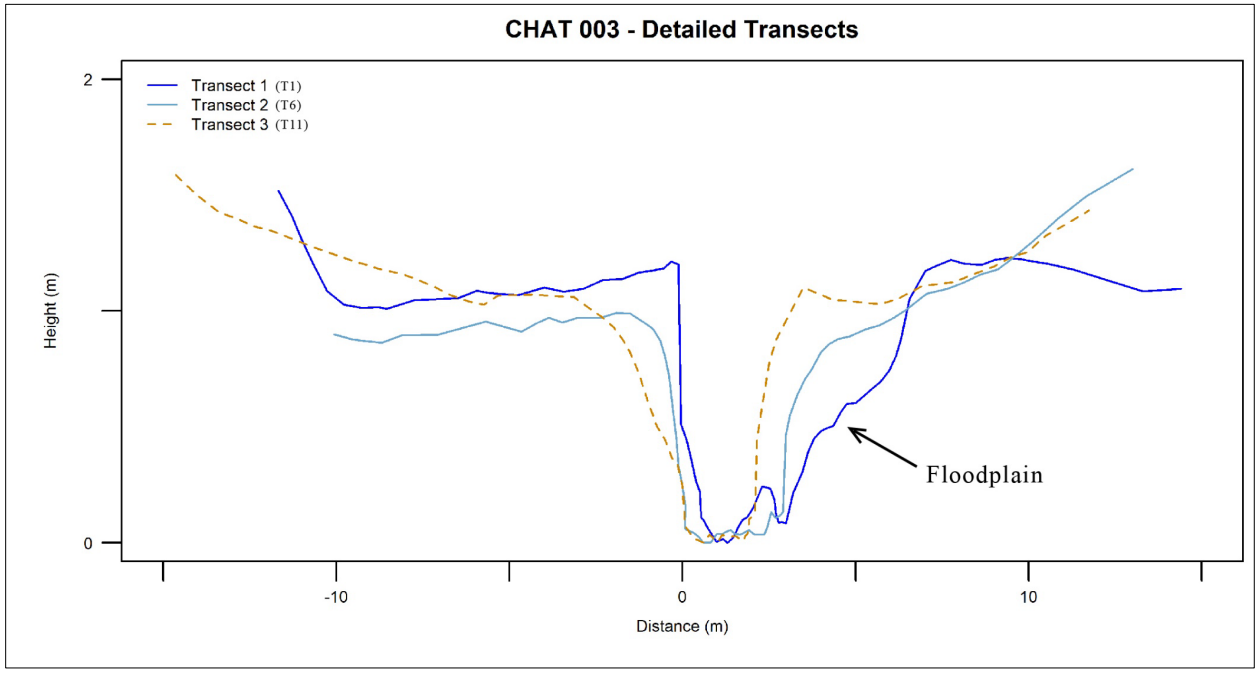


Figure 11. Comparison of the detailed transects at CHAT003. The location of the left channel-full points for each transect are normalized to allow for comparisons between transects.

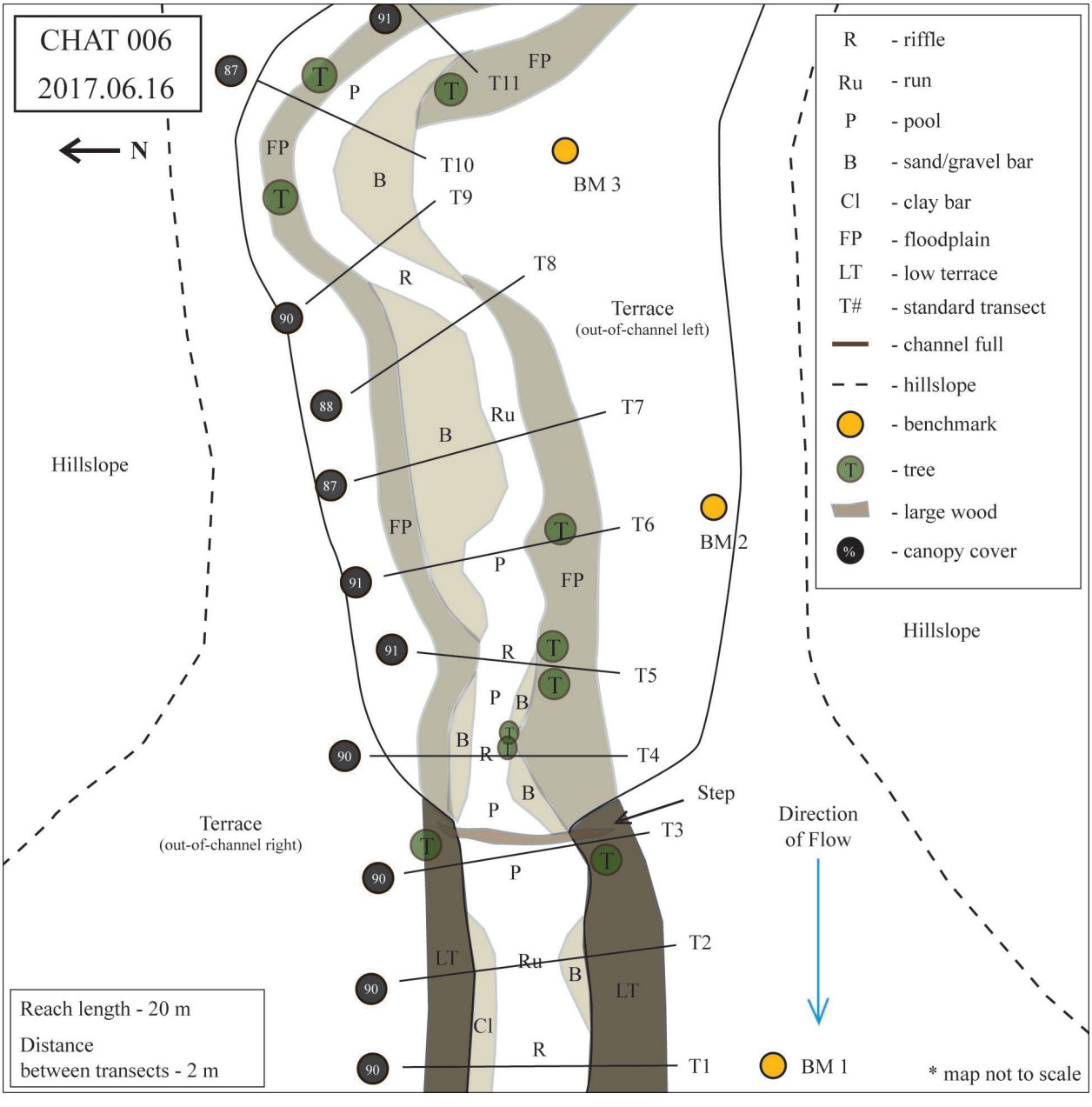


Figure 12. Reach-scale map of CHAT006. Important geomorphic surfaces and in-channel features are labeled to provide a context for the standard and detailed transect information provided in this report. The canopy cover circles are varying shades of grey which indicate the amount of canopy cover at each transect (high and low coverages are labeled).

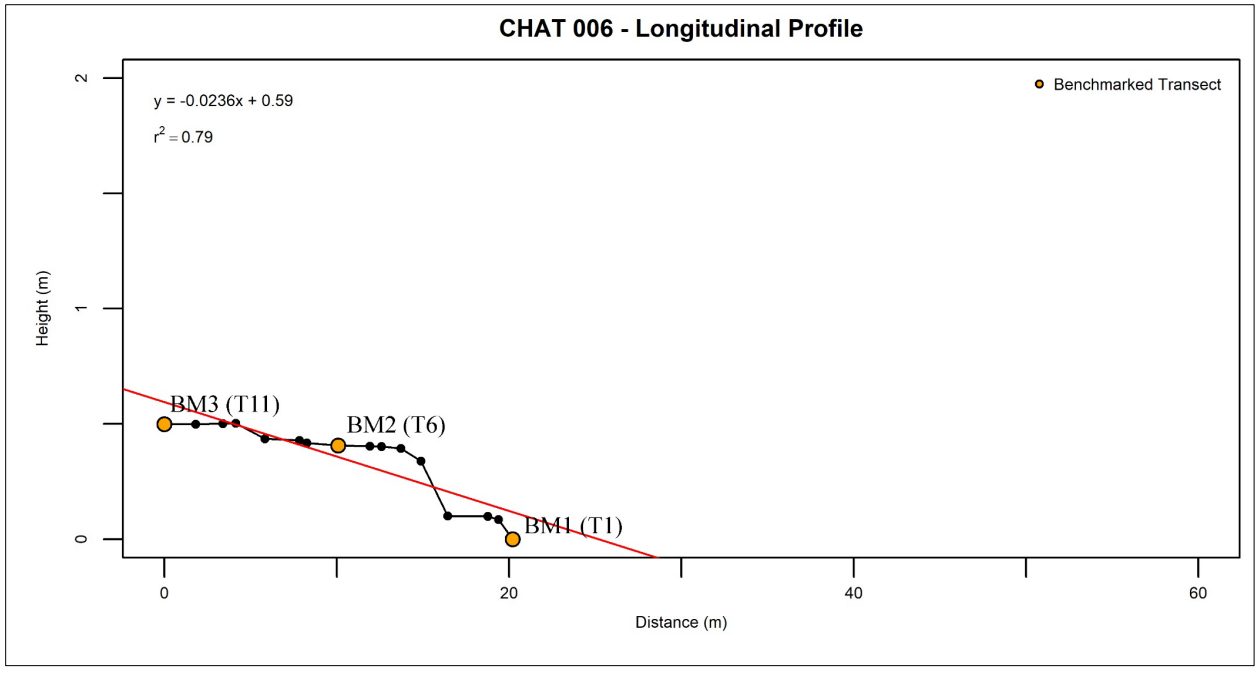


Figure 13. Longitudinal profile for CHAT006. The red line on the graph corresponds to the interpreted slope of the reach. The r^2 value describes the strength of the trend line.

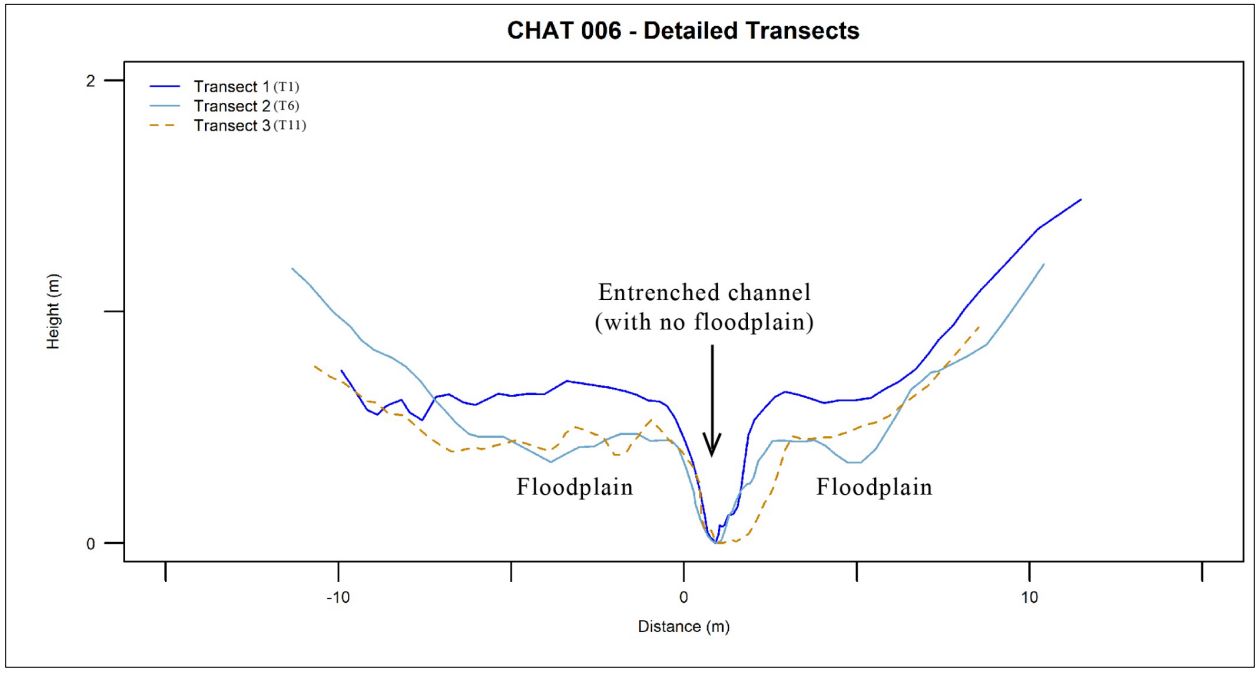


Figure 14. Comparison of the detailed transects at CHAT006. The location of the left channel-full points for each transect are normalized to allow for comparisons between transects.

CHAT009—Fox Creek

On June 14, 2017, stream survey data were collected at CHAT009. CHAT009 is located along a portion of Fox Creek (a first-order stream near the Sope Creek Hiking trail). Fox Creek can be accessed using the Sope Creek Hiking trail to get to within 50 meters (164 ft) of the monitored reach. CHAT009 is approximately 175 meters (574 ft) upstream of a culvert that runs under the adjacent apartment complex and empties into Sope Creek. The reach that was surveyed was 20 meters (65.6 ft) long with 2 meters (6.6 ft) between transects.

The monitored portion of Fox Creek was characterized by an abundance of low, potentially slump-cored, benches along the sides of the channel at T1, T2, T5, and T8 through T11 (Figure 15). CHAT009 was paired with CHAT012 because they are similarly sized (0.51 km^2 [CHAT009] and 0.30 km^2 [CHAT012]) and similar land use/landcover (Table 4), and both are located in the southern portion of the park. Water surface slope (longitudinal profile) for this section of Fox Creek was 0.0144 m/m (Table 5). The longitudinal profile was relatively flat with only one slight increase in slope (between T3 and T4; Figure 16). The detailed transects were surveyed on T3 (BM1), T8 (BM2), and T11 (BM3). No floodplains were surveyed on any of the detailed transects (Figure 17). Benches were identified on detailed transects 1 (T3) and 3 (T11) and a side bar was observed on detailed transect 2 (T8) on river left. Survey results for CHAT009 can be found in Appendix E.

CHAT012—Cabin Creek

On June 13, 2017, stream survey data were collected at CHAT012. CHAT012 is located along Cabin Creek (a first-order stream in the Palisades unit). Cabin Creek can be accessed by taking the first hiking trail on Indian Trail NW down to the reach. The reach that was surveyed was 20 meters (65.6 ft) long with 2 meters (6.6 ft) between transects.

Cabin Creek's left bank was actively eroding into the trail between T5 and T6 (Figure 18). Floodplains were observed in the upstream and middle portions of the monitored reach. As mentioned in CHAT009's description, CHAT012 was paired with CHAT009 because of similarities in basin area, land use/land cover, and location within the park. Water surface slope (longitudinal profile) for this section of Cabin Creek was 0.0234 m/m (Table 5). The longitudinal profile was relatively consistent with only one section with higher slope (between T3 and T4; Figure 19). The detailed transects were surveyed on T1 (BM1), T6 (BM2), and T9 (BM3). Detailed transect 2 (T6) and 3 (T9) had small floodplains while no floodplain was observed on detailed transect 1 (T1; Figure 20). Survey results for CHAT012 can be found in Appendix F.

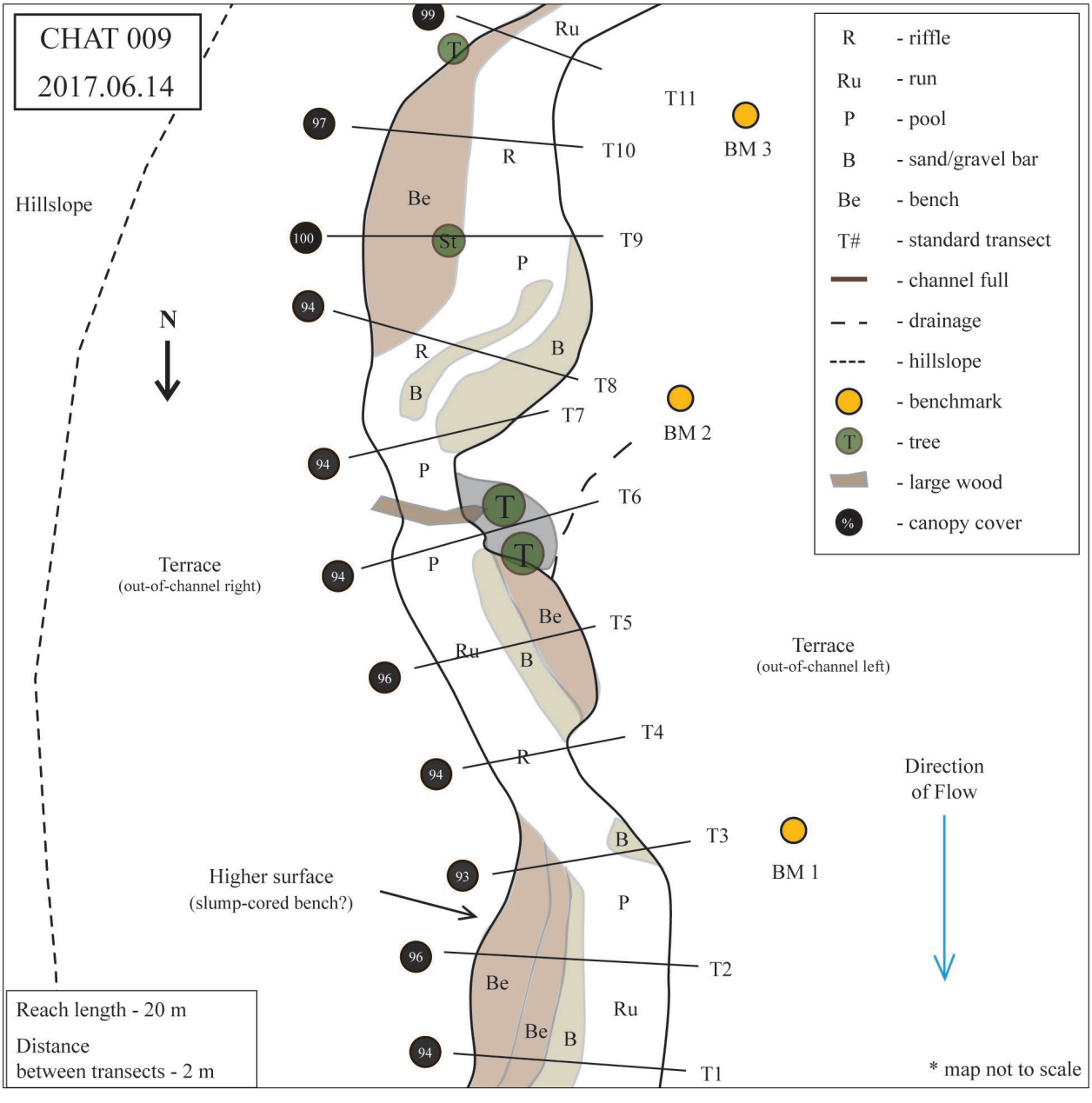


Figure 15. Reach-scale map of CHAT009. Important geomorphic surfaces and in-channel features are labeled to provide a context for the standard and detailed transect information provided in this report. The canopy cover circles are varying shades of grey which indicate the amount of canopy cover at each transect (high and low coverages are labeled).

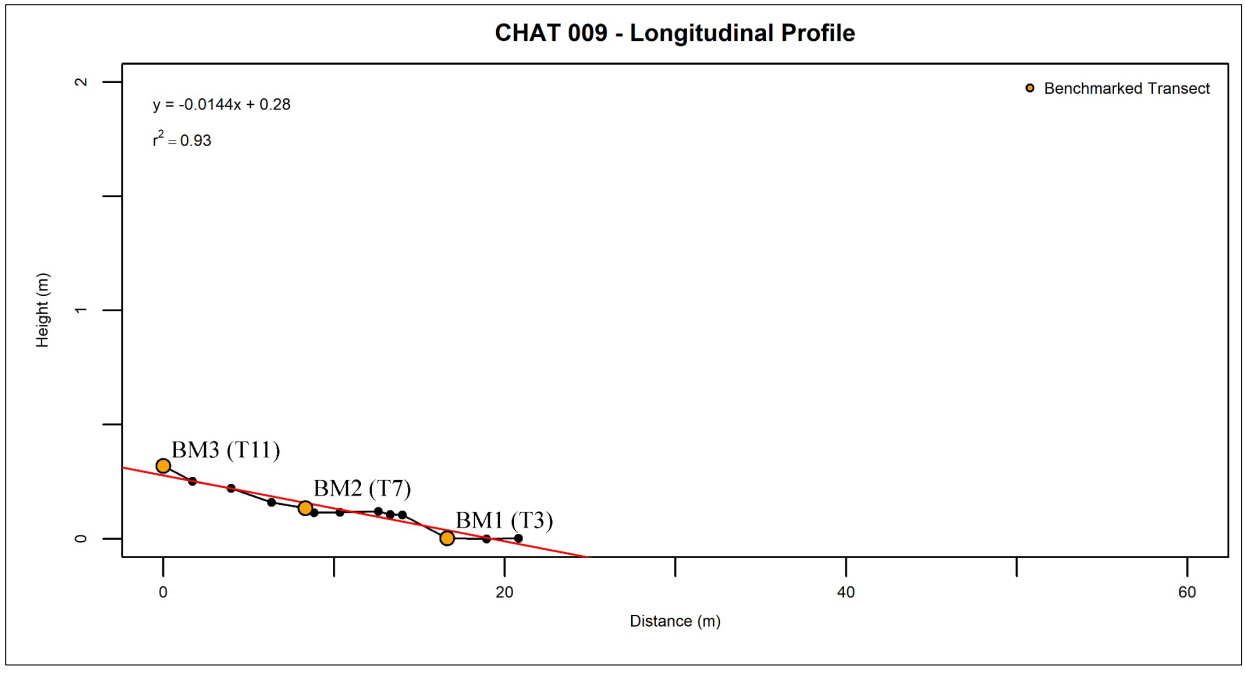


Figure 16. Longitudinal profile for CHAT009. The red line on the graph corresponds to the interpreted slope of the reach. The r^2 value describes the strength of the trend line.

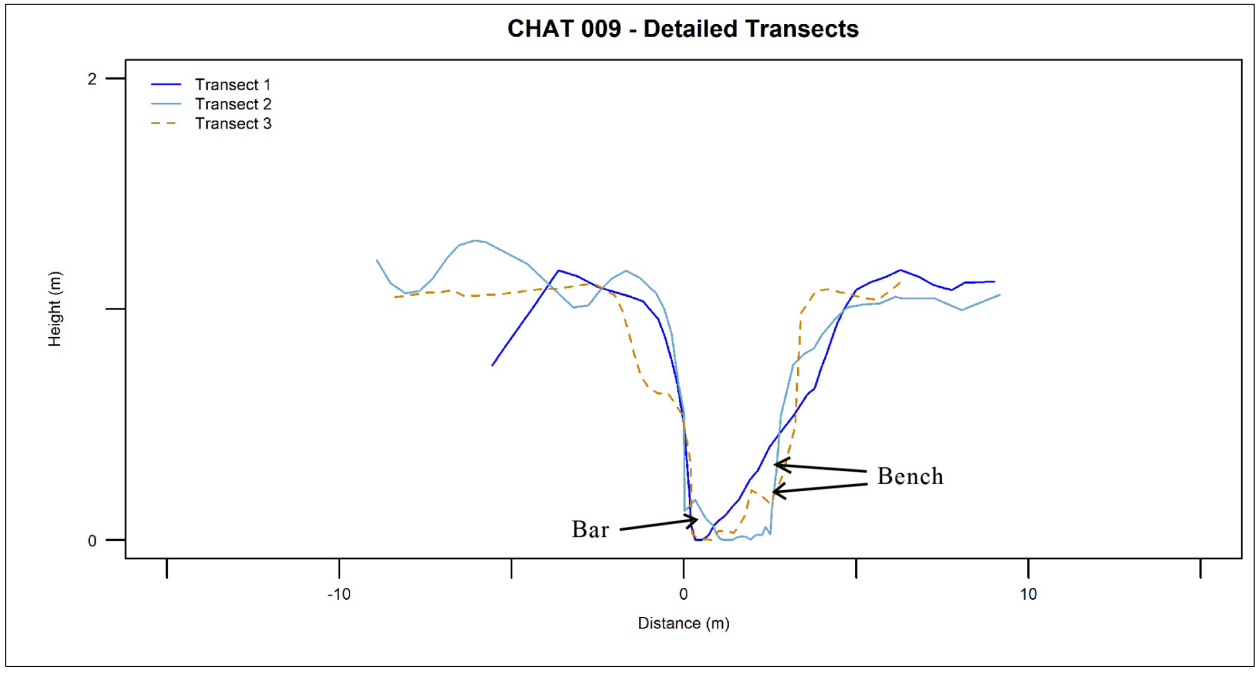


Figure 17. Comparison of the detailed transects at CHAT009. The location of the left channel-full points for each transect are normalized to allow for comparisons between transects.

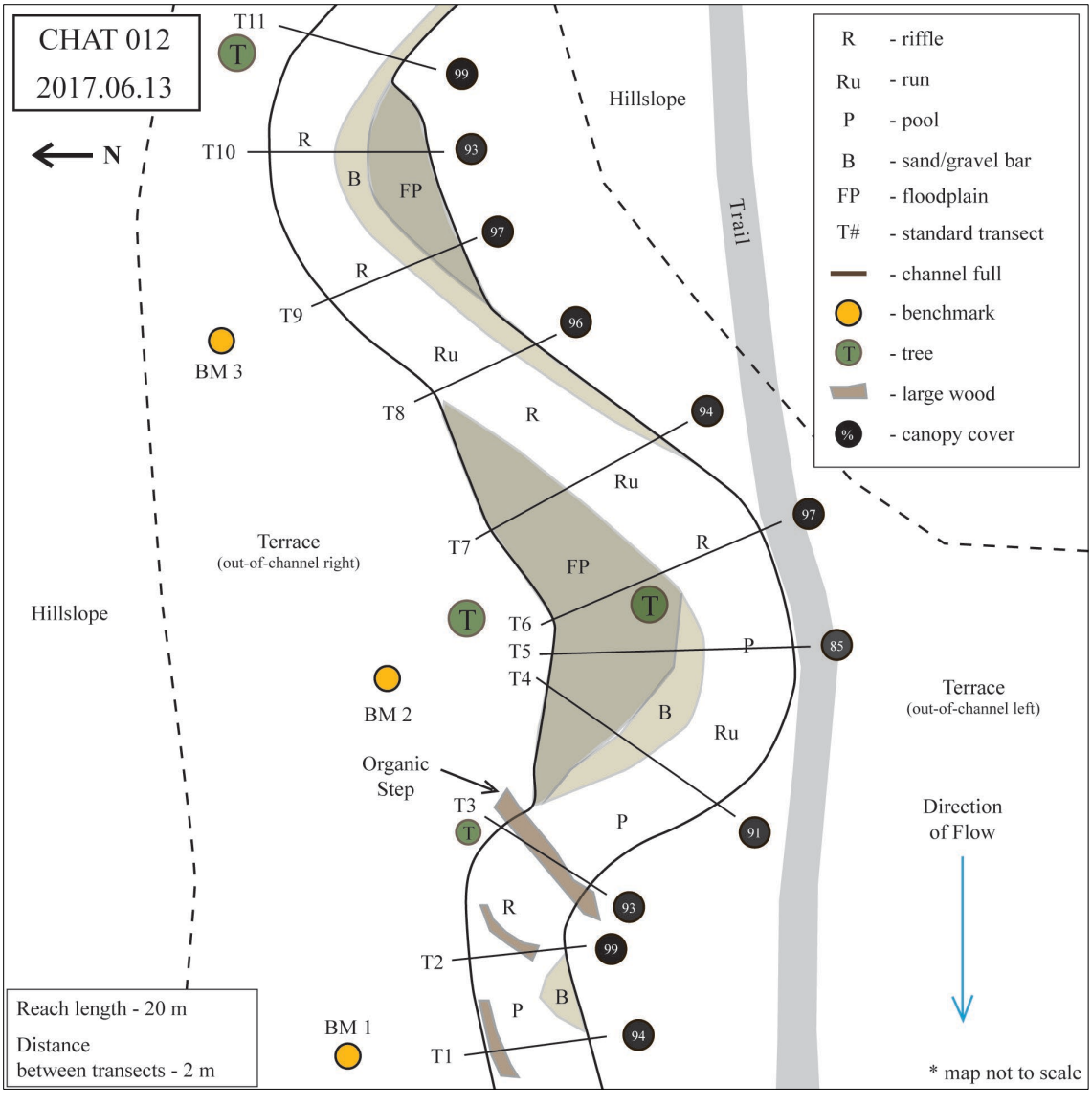


Figure 18. Reach-scale map of CHAT012. Important geomorphic surfaces and in-channel features are labeled to provide a context for the standard and detailed transect information provided in this report. The canopy cover circles are varying shades of grey which indicate the amount of canopy cover at each transect (high and low coverages are labeled).

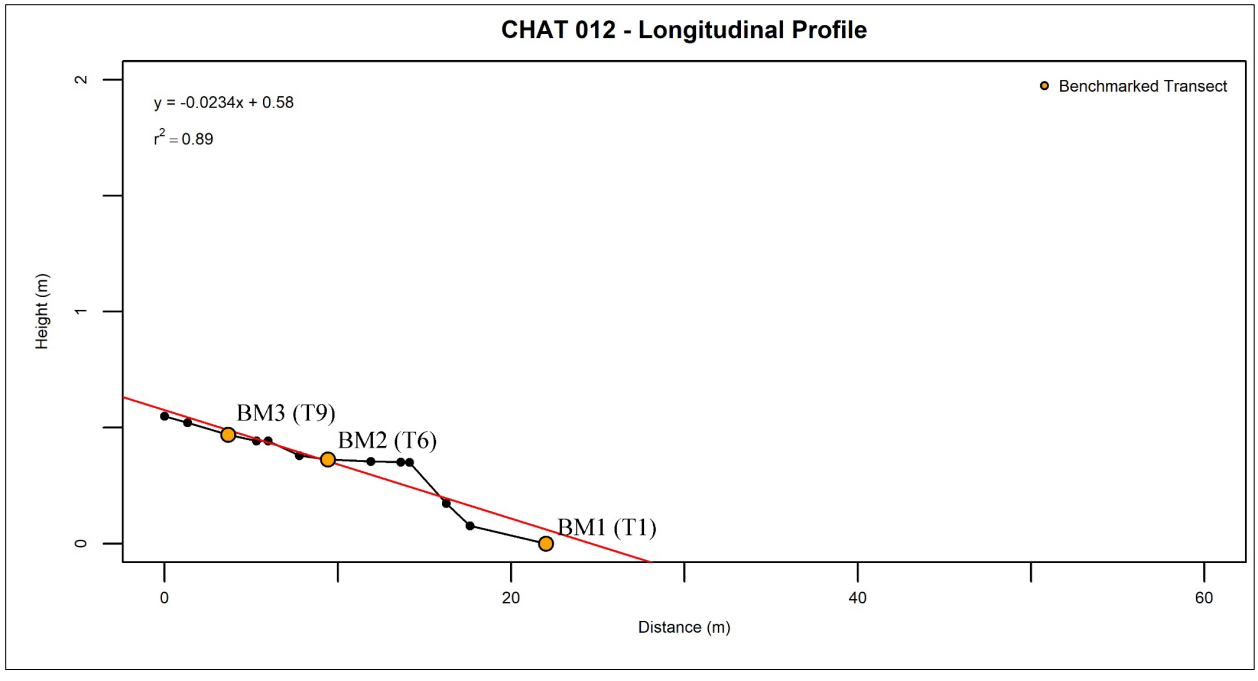


Figure 19. Longitudinal profile for CHAT012. The red line on the graph corresponds to the interpreted slope of the reach. The r^2 value describes the strength of the trend line.

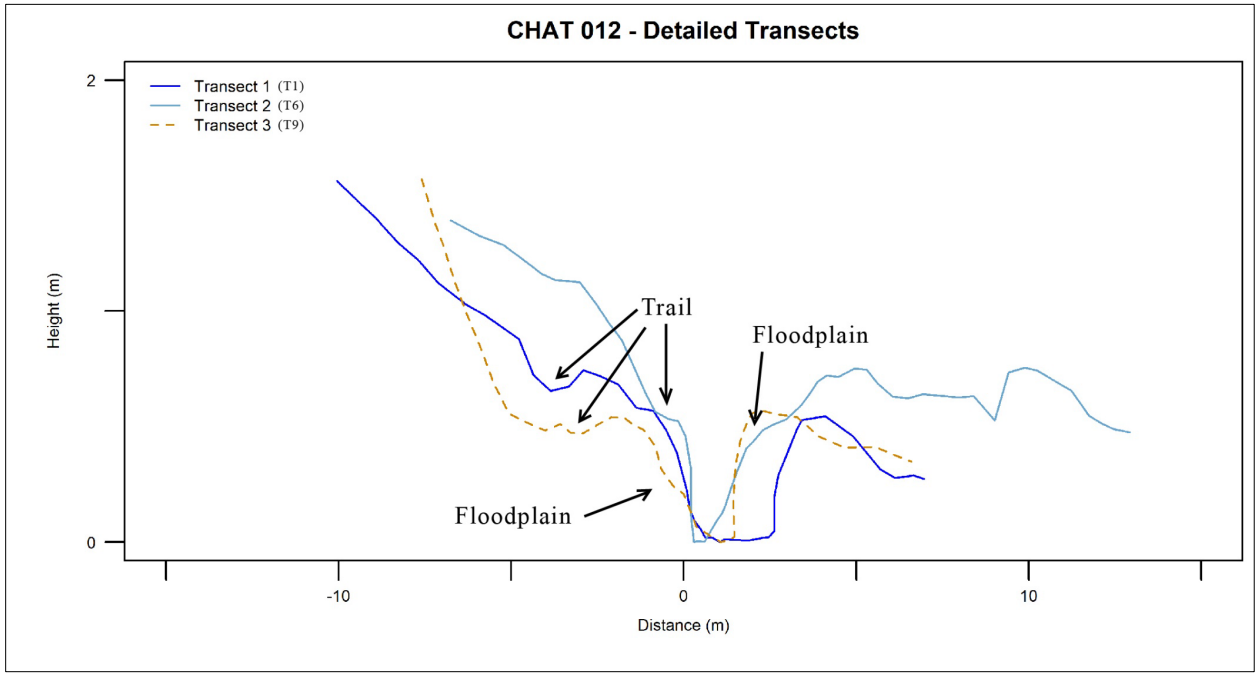


Figure 20. Comparison of the detailed transects at CHAT012. The location of the left channel-full points for each transect are normalized to allow for comparisons between transects.

Basin Characteristics

The first-order watersheds range in size from 0.20 square kilometers (0.08 sq mi; CHAT006) to 0.51 square kilometers (0.2 sq mi; CHAT003 and CHAT009; Table 3). Chattahoochee River National Recreation Area manages between 34% (CHAT012) and 83% (CHAT009) of these watersheds. Though the drainage areas of CHAT002 and CHAT012 are similar (within 0.02 square kilometers [0.008 sq mi]), CHAT002's watershed is much more dissected (i.e., total stream length is more than five times CHAT012's). Interestingly, CHAT002 also has a greater drainage density (TSL/DA, 1.64 km/km^2) than all the other first-order watersheds (0.35-1.32 km/km^2). The three northern sites (CHAT002, CHAT003, and CHAT006) have the highest entire stream gradients (0.0532–0.0616 m/m; Table 3). CHAT002 had the highest segment gradient (0.084 m/m) while CHAT006 had the lowest segment gradient (0.0186 m/m). The watershed with the highest average slope drains to CHAT012 (11.87°) and CHAT006 had the lowest average watershed slope (8.36°, Table 3). CHAT012 also had the least variability in slope (CV = 0.45 compared to 0.54–0.60). Basin shape indicates that CHAT002 (0.17) and CHAT006 (0.18) have long and narrow drainages and the other watershed are more circular (0.26–0.30, Table 3). CHAT006 has the least relief (55 m) while CHAT002 and CHAT003 have the highest relief (approximately 85 meters [278.8 ft]) of the first-order watersheds. All first-order watersheds have high forest cover (75% [CHAT009] up to 86% [CHAT003]) except for CHAT006 (37%, Table 4). CHAT006 has the highest residential/suburban land cover (46%, Developed Open and Low) as well as the most commercial and/or industrial land cover (16% Developed Medium and High).

Habitat Characteristics

The geomorphic channel unit (GCU) types and distributions of the five first-order streams are quite different (Table 6). On opposite ends of the energy spectrum, CHAT003 is mostly riffle (83%) and CHAT006 is mostly pool (58%). The other three sites are a mixture of riffles, runs, and pools. The pebble count data corroborates the interpretation of differences in energy between CHAT003 and CHAT006 (Table 7). The mean diameter of the pebbles at CHAT003 (39.05 millimeters [1.54 inches {in}) is significantly different (coarser) than all sites (10.93 millimeters [0.43 in; CHAT006] up to 23.68 millimeters [0.93 in; CHAT009]) except for CHAT002 (29.93 millimeters [1.18 in], Table 8). Conversely, the mean diameter of the pebbles at CHAT006 is significantly different (finer than all other first-order streams). The mean diameter of the pebbles at the other three sites are not significantly different from each other.

The number of pieces of LWD in the first-order streams ranged from two (CHAT006 and CHAT012) to 10 (CHAT003; Table 9). Though CHAT003 had the most pieces of LWD (10), CHAT002 had the highest volume of LWD per channel area (0.0105 m^3/m^2). The LWD at CHAT002 was composed of two large tree falls, both of which are bridging the channel (one at T4 and the other just downstream of T8; Figure 7). CHAT003 was also influenced by two tree falls (near T3 and between T9 and T11). Though there were only two pieces of LWD at CHAT006 and CHAT012, these pieces of large wood are influencing these streams through step creation (Figures 12 and 18). Canopy cover at all five sites was around 90% (Table 10). CHAT006 had the lowest average canopy cover (89%) while CHAT002 had the highest (96%).

Table 6. Comparison of GCUs observed in the area between transects for the first-order streams at Chattahoochee River NRA. The data describe the percent coverage of each type of GCU.

GCU Type	Site Number	Frequency	Max (%)	Mean (%)	SD (%)
Riffle	CHAT002	9	100	59	32
	CHAT003	10	100	83	19
	CHAT006	6	90	25	29
	CHAT009	6	100	45	42
	CHAT012	6	100	50	47
Run	CHAT002	3	60	12	23
	CHAT003	4	15	5	7
	CHAT006	3	60	12	21
	CHAT009	4	100	25	37
	CHAT012	3	50	15	24
Glide	CHAT002	0	0	0	0
	CHAT003	0	0	0	0
	CHAT006	0	0	0	0
	CHAT009	0	0	0	0
	CHAT012	0	0	0	0
Pool	CHAT002	5	100	30	36
	CHAT003	5	50	13	18
	CHAT006	10	100	58	37
	CHAT009	7	100	30	38
	CHAT012	4	100	30	42
Step	CHAT002	0	0	0	0
	CHAT003	0	0	0	0
	CHAT006	1	40	4	13
	CHAT009	0	0	0	0
	CHAT012	1	50	5	16

Table 7. Comparison of the particle size distributions of bed sediment (in millimeters [mm]) from the pebble count pebble surveys conducted at the first-order stream sites. The subscripts indicate the percent of the sample that is smaller than the reported diameter.

Statistic (mm)	CHAT002 (n=100)	CHAT003 (n=100)	CHAT006 (n=100)	CHAT009 (n=100)	CHAT012 (n=100)
Min	2.00	2.00	2.00	2.00	2.00
D_5	2.00	2.00	2.00	2.00	2.00
D_{16}	6.00	5.00	3.00	6.00	5.00
D_{50}	21.50	19.50	9.50	17.50	14.50
Mean	29.93	39.05	10.93	23.68	22.21
D_{84}	52.48	69.16	18.00	45.32	33.32
D_{95}	85.75	144.50	23.05	63.05	75.15
Max	152.00	269.00	50.00	110.00	135.00

Table 8. Significance of the differences in means in the pebble counts, thalweg depths, and thalweg positions of the first-order streams based on a post-hoc Tukey analysis. The significance of the differences is indicated by: "–"not significant; "*" p-value <0.05, "**" p-value <0.01, and "***" p-value <0.001. F-value and p-value of ANOVA results are reported as footnotes [m—meters; mm—millimeters].

Pairings	n[1]	Pebble Count (mm)[2]	P-value	Sig.	n[3]	Thalweg Depth (m)[4]	P-value	Sig.	Thalweg Position (%)[5]	P-value	Sig.
CHAT003 - CHAT002	100	9.10	0.168	–	11	0.033	0.446	–	8.64	–	–
CHAT006 - CHAT002	100	-19.00	< 0.001	***	11	0.050	0.088	–	-5.91	–	–
CHAT009 - CHAT002	100	-6.35	0.524	–	11	-0.013	0.964	–	3.64	–	–
CHAT012 - CHAT002	100	-7.72	0.320	–	11	-0.008	0.993	–	12.73	–	–
CHAT006 - CHAT003	100	-28.10	< 0.001	***	11	0.017	0.897	–	-14.55	–	–
CHAT009 - CHAT003	100	-15.45	0.002	**	11	-0.045	0.145	–	-5.00	–	–
CHAT012 - CHAT003	100	-16.82	< 0.001	***	11	-0.041	0.228	–	4.09	–	–
CHAT009 - CHAT006	100	12.65	0.017	*	11	-0.063	0.017	*	9.55	–	–

[1] Number of pebbles

[2] $F(5,100) = 12.944$, $p < 0.001$

[3] Number of measurements for thalweg depth and position

[4] $F(5,11) = 4.076$, $p = 0.006$

[3] $F(5,11) = 0.927$; $p = 0.455$

Table 8 (continued). Significance of the differences in means in the pebble counts, thalweg depths, and thalweg positions of the first-order streams based on a post-hoc Tukey analysis. The significance of the differences is indicated by: "–"not significant; "*" p-value <0.05, "**" p-value <0.01, and "***" p-value <0.001.
F-value and p-value of ANOVA results are reported as footnotes [m—meters; mm—millimeters].

Pairings	n[1]	Pebble Count (mm)[2]	P-value	Sig.	n[3]	Thalweg Depth (m)[4]	P-value	Sig.	Thalweg Position (%)[5]	P-value	Sig.
CHAT012 - CHAT006	100	11.28	0.046	*	11	-0.058	0.031	*	18.64	–	–
CHAT012 - CHAT009	100	-1.37	0.997	–	11	0.005	0.999	–	9.09	–	–

[1] Number of pebbles

[2] $F(5,100) = 12.944$, $p < 0.001$

[3] Number of measurements for thalweg depth and position

[4] $F(5,11) = 4.076$, $p = 0.006$

[3] $F(5,11) = 0.927$; $p = 0.455$

Table 9. Comparison of the summary statistics for the LWD measured at the first-order stream sites (m—meters; SD—Standard deviation].

Statistic	Site Number	n	Length (m)	Diameter (m)	Volume (m^3)
Min	CHAT002	6	1.20	0.10	0.02
	CHAT003	10	1.23	0.09	0.01
	CHAT006	2	1.10	0.19	0.03
	CHAT009	3	1.17	0.12	0.01
	CHAT012	2	1.10	0.10	0.01
Mean	CHAT002	6	2.74	0.27	0.36
	CHAT003	10	3.13	0.21	0.16
	CHAT006	2	1.10	0.21	0.04
	CHAT009	3	2.28	0.15	0.04
	CHAT012	2	1.55	0.15	0.03
Max	CHAT002	6	4.84	0.64	1.56
	CHAT003	10	5.28	0.65	0.66
	CHAT006	2	1.10	0.22	0.04
	CHAT009	3	3.25	0.21	0.08
	CHAT012	2	2.00	0.19	0.06
SD	CHAT002	6	1.41	0.20	0.61
	CHAT003	10	1.19	0.19	0.24
	CHAT006	2	0.00	0.02	0.01
	CHAT009	3	1.05	0.05	0.04
	CHAT012	2	0.64	0.06	0.03

Table 9 (continued). Comparison of the summary statistics for the LWD measured at the first-order stream sites (m—meters; SD—Standard deviation].

Statistic	Site Number	n	Length (m)	Diameter (m)	Volume (m^3)
Sum	CHAT002	6	–	–	2.14
	CHAT003	10	–	–	1.57
	CHAT006	2	–	–	0.07
	CHAT009	3	–	–	0.13
	CHAT012	2	–	–	0.07
Per Channel Area (m^3/m^2)	CHAT002	–	–	–	0.0105
	CHAT003	–	–	–	0.0067
	CHAT006	–	–	–	0.0033
	CHAT009	–	–	–	0.0014
	CHAT012	–	–	–	0.0008

Table 10. Comparison of the variability in canopy cover at the first-order stream sites [SD—Standard deviation; CV—Coefficient of variation].

Site Number	n	Min (%)	Mean (%)	Max (%)	SD (%)	CV
CHAT002	11	91	96	99	2	0.02
CHAT003	11	85	91	96	3	0.04
CHAT006	11	87	89	91	2	0.02
CHAT009	11	93	95	100	2	0.02
CHAT012	11	85	94	99	4	0.04

Average thalweg depth ranged from 0.05 meters (0.16 ft; CHAT009 and CHAT012) to 0.11 meters (0.36 ft; CHAT006; Table 11). The deepest maximum thalweg depth (deepest pool) was at CHAT003 (0.26 meters [0.85 ft]). Differences in thalweg depths between CHAT006 (0.11 meters [0.36 ft]) and CHAT009 as well as CHAT012 (both had an average of 0.05 meters [0.16 ft]) were statistically significant (Table 8). CHAT006 had the most variable thalweg position (highest CV; 0.68) and CHAT012's thalweg position was the least variable (0.43, Table 11).

Table 11. Comparison of reach-scale averaged thalweg conditions at the first-order stream sites. Depth measurements are in meters and the position is the percent distance from the left bank[1] [SD—Standard deviation; CV—Coefficient of variation].

Thalweg Characteristic	Site Number	n	Min	Mean	Max	SD	CV
Depth (m)	CHAT002	11	0.03	0.06	0.14	0.03	0.52
	CHAT003	11	0.05	0.09	0.26	0.06	0.63
	CHAT006	11	0.03	0.11	0.21	0.07	0.59
	CHAT009	11	0.02	0.05	0.08	0.02	0.47
	CHAT012	11	0.02	0.05	0.12	0.03	0.57
Position[1] (%)	CHAT002	11	10	43	90	24	0.56
	CHAT003	11	20	51	90	24	0.47
	CHAT006	11	5	37	80	25	0.68
	CHAT009	11	5	46	90	28	0.61
	CHAT012	11	10	55	80	24	0.43

[1]position is percent distance from left bank

Channel Morphology

Average wetted width ranged from 0.97 meters (3.18 ft; CHAT009) to 1.68 meters (5.51 ft; CHAT003; Table 12). The difference in wetted width between the two reaches with the smallest average width (CHAT006 [0.99 meters or 3.25 ft] and CHAT009 [0.97 meters or3.18 ft]) and the reach with the largest average width (CHAT003; 1.68 meters or 5.51 ft) were statistically significant (Table 13). CHAT006 had the most variable wetted width (CV = 0.59) and CHAT003 was the least variable (0.23). Average active channel width ranged from 1.38 meters (4.53 ft; CHAT012) to 2.21 meters (7.25 ft; CHAT003; Table 12). The differences in active channel widths between the two widest reaches (CHAT002 and CHAT003 [both were 1.20 meters {3.94 ft}]) and the two narrowest reaches (CHAT006 [0.86 meters or 2.82 ft] and CHAT012 [1.00 meter or 3.3 ft]) were statistically significant (Table 13). Average bankfull width ranged from 2.16 meters (7.09 ft; CHAT012) to 3.39 meters (11.12 ft; CHAT006; Table 12). No bankfull widths were measured at CHAT009 (i.e., no floodplains were observed within the reach). The variability in bankfull widths were relatively low for all reaches (CV = 0.20–0.27) except for CHAT003 (CV = 0.46). Average channel-full width ranged from 4.02 meters (13.19 ft; CHAT012) to 11.16 meters (36.61 ft; CHAT006; Table 12). CHAT006 had the widest and narrowest channel-full width (22.07 meters and 2.43 meters [72.41 and 7.97 ft], respectively). The differences in mean channel-full width between CHAT006 (11.16 meters [36.61 ft]) and all other first-order streams were statistically significant (4.02 meters [13.19 ft; CHAT012] up to 6.78 meters [22.24 ft; CHAT002], Table 13). In addition to having the widest average channel-full widths, CHAT002 and CHAT006 also had the most variability in channel-full widths (CV = 0.53 and 0.56, respectively; Table 12).

Table 12. Comparison of reach-scale averaged width characteristics of the first-order stream sites [m—meters; SD—Standard deviation; CV—Coefficient variation].

Widths	Site Number	n	Min (m)	Mean (m)	Max (m)	SD (m)	CV
Wetted	CHAT002	11	0.67	1.52	2.60	0.59	0.39
	CHAT003	11	1.03	1.68	2.46	0.39	0.23
	CHAT006	11	0.28	0.99	2.17	0.58	0.59
	CHAT009	11	0.60	0.97	1.49	0.35	0.36
	CHAT012	11	0.64	1.13	2.00	0.44	0.39
Active Channel	CHAT002	11	1.20	2.03	3.02	0.54	0.27
	CHAT003	11	1.20	2.21	3.49	0.67	0.30
	CHAT006	11	0.86	1.41	2.04	0.43	0.31
	CHAT009	11	1.33	1.86	2.66	0.43	0.23
	CHAT012	11	1.00	1.38	2.10	0.32	0.23
Bankfull	CHAT002	5	2.03	2.49	3.40	0.56	0.23
	CHAT003	3	1.71	2.58	3.93	1.18	0.46
	CHAT006	8	2.35	3.39	4.00	0.66	0.20
	CHAT009	0	–	–	–	–	–
	CHAT012	6	1.49	2.16	3.04	0.58	0.27
Channel-full	CHAT002	11	4.14	6.78	15.48	3.61	0.53
	CHAT003	11	3.34	4.67	7.42	1.12	0.24
	CHAT006	11	2.43	11.16	22.07	6.24	0.56
	CHAT009	11	3.56	4.67	5.74	0.86	0.18
	CHAT012	11	2.45	4.02	6.33	1.15	0.29

Table 13. Significance of the differences in the **mean** wetted widths, active channel widths, and channel-full widths of the first-order streams based on a post-hoc Tukey analysis. The significance of the differences is indicated by: "–"not significant; "*" p-value <0.05, "**" p-value <0.01, and "***" p-value <0.001. F-value and p-value of ANOVA results are reported as footnotes [m—meters].

Pairings	n[1]	Wetted Width (m)	P-value[2]	Sig	Active Channel Width (m)	P-value[3]	Sig	Channel-full Width (m)	P-value[4]	Sig
CHAT003 - CHAT002	11	0.154	0.943	–	0.183	0.906	–	-2.110	0.574	–
CHAT006 - CHAT002	11	-0.536	0.082	–	-0.615	0.038	*	4.378	0.026	*
CHAT009 - CHAT002	11	-0.554	0.068	–	-0.171	0.925	–	-2.105	0.577	–
CHAT012 - CHAT002	11	-0.392	0.324	–	-0.649	0.025	*	-2.759	0.307	–
CHAT006 - CHAT003	11	-0.690	0.012	*	-0.798	0.003	**	6.488	< 0.001	***
CHAT009 - CHAT003	11	-0.707	0.010	**	-0.354	0.451	–	0.005	> 0.999	–
CHAT012 - CHAT003	11	-0.545	0.074	–	-0.832	0.002	**	-0.649	0.991	–
CHAT009 - CHAT006	11	-0.017	> 0.999	–	0.445	0.228	–	-6.484	< 0.001	***
CHAT012 - CHAT006	11	0.145	0.954	–	-0.034	> 0.999	–	-7.137	< 0.001	***
CHAT012 - CHAT009	11	0.162	0.932	–	-0.478	0.168	–	-0.654	0.990	–

[1] Number of measurements for wetted width, active channel width, and channel-full width.

[2] $F(5,11) = 4.985$, $p = 0.002$

[3] $F(5,11) = 6.239$, $p < 0.001$

[4] $F(5,11) = 8.541$; $p < 0.001$

Mean minimum bank heights (lowest bank [either bankfull or channel-full]) ranged from approximately 0.57 meters (1.87 ft; CHAT006 and CHAT012) to approximately 0.95 meters (3.12 ft; other three first-order sites; Table 14). The maximum minimum bank height (2.34 meters [7.68 ft]) was measured at CHAT002 while CHAT012 had the lowest maximum minimum bank height (0.82 meters [2.69 ft]). Minimum bank heights were the most variable at CHAT002 (CV = 0.44) while CHAT009 had the most consistent minimum bank heights (CV = 0.14). No bankfull heights were measured at CHAT009 because no floodplains were observed within the reach. The other four first-order sites had average bankfull heights ranging from 0.33 meters (1.08 ft; CHAT003) to 0.45 meters (1.48 ft; CHAT006; Table 14). CHAT003 had the most variable bankfull heights (CV = 0.49), though only three bankfull heights were measured. CHAT006 and CHAT012 had the lowest average channel-full bank heights (0.67 meters and 0.63 meters [2.20 and 2.07 ft], respectively; Table 14). The other three first-order sites had channel-full banks around 1 meter (3.3 ft) high. The differences in channel-full heights for CHAT006 and CHAT012 compared to the other first-order streams was statistically significant (Table 15). Variability in channel-full heights is relatively low, except CHAT002's channel-full height CV (0.33) is almost two times as high as the rest of the first-order streams (CVs range from 0.14 [CHAT006 and 009] up to 0.19 [CHAT003]; Table 14).

Table 14. Comparison of reach-scale averaged bank heights of the first-order stream sites [m—meters; SD—Standard deviation; CV—Coefficient of variation].

Bank Heights	Site Number	n	Min	Mean	Max	SD	CV
Minimum Bank Height[1,2] (m)	CHAT002	22	0.29	0.90	2.34	0.39	0.44
	CHAT003	22	0.23	0.94	1.39	0.30	0.32
	CHAT006	22	0.34	0.58	0.84	0.14	0.24
	CHAT009	22	0.67	0.97	1.19	0.14	0.14
	CHAT012	22	0.25	0.56	0.82	0.15	0.27
Bankfull Height[1,3] (m)	CHAT002	5	0.29	0.38	0.45	0.06	0.16
	CHAT003	3	0.23	0.33	0.51	0.16	0.49
	CHAT006	14	0.34	0.45	0.55	0.08	0.17
	CHAT009	0	–	–	–	–	–
	CHAT012	7	0.25	0.37	0.47	0.09	0.24
Channel-full Height[1] (m)	CHAT002	22	0.61	1.02	2.34	0.34	0.33
	CHAT003	22	0.63	1.03	1.39	0.20	0.19
	CHAT006	22	0.43	0.67	0.84	0.10	0.14
	CHAT009	22	0.67	0.97	1.19	0.14	0.14
	CHAT012	22	0.33	0.63	0.82	0.11	0.17

[1]above thalweg

[2] this height refers to the lowest bank height on either side (bankfull or channel-full)

[3]statistics are based on the transects where feature is present (# in parentheses)

Table 15. Significance of the differences of the channel-full heights, bank angles, and vegetative cover of the first-order streams based on a post-hoc Tukey analysis. The significance of the differences is indicated by: "–"not significant; "*" p-value <0.05, "**" p-value <0.01, and "***" p-value <0.001. F-value and p-value of ANOVA results are reported as footnotes [m—meters].

Pairings	n[1]	Channel-full Height (m)	P-value[2]	Sig.	Bank Angle (°)	P-value[3]	Sig.	Vegetative Cover (%)	P-value[4]	Sig.
CHAT003 - CHAT002	22	0.012	> 0.999	–	13.464	–	–	8.182	0.798	–
CHAT006 - CHAT002	22	-0.346	< 0.001	***	-7.882	–	–	-22.955	0.019	*
CHAT009 - CHAT002	22	-0.052	0.905	–	-5.182	–	–	-14.318	0.297	–
CHAT012 - CHAT002	22	-0.391	< 0.001	***	4.382	–	–	-2.727	0.996	–
CHAT006 - CHAT003	22	-0.358	< 0.001	***	-21.345	–	–	-31.136	< 0.001	***
CHAT009 - CHAT003	22	-0.064	0.818	–	-18.645	–	–	-22.500	0.023	*
CHAT012 - CHAT003	22	-0.403	< 0.001	***	-9.082	–	–	-10.909	0.573	–
CHAT009 - CHAT006	22	0.294	< 0.001	***	2.700	–	–	8.636	0.765	–
CHAT012 - CHAT006	22	-0.045	0.939	–	12.264	–	–	20.227	0.053	–
CHAT012 - CHAT009	22	-0.340	< 0.001	***	9.564	–	–	11.591	0.514	–

[1] Number of measurements for Channel-full height, bank angle, and vegetative cover.

[2] $F(5,11) = 22.131$, $p < 0.001$

[3] $F(5,11) = 2.260$, $p = 0.068$

[4] $F(5,11) = 5.606$; $p < 0.001$

The average depth of the undercuts measured on the first-order streams was approximately 0.24 meters (0.79 ft) for all sites except for CHAT006 (0.12 meters [0.39 ft]; Table 16). Maximum undercut depth was measured at CHAT009 (0.94 meters [3.08 ft]). CHAT009 also had the greatest variability in undercut depth (CV = 1.19) followed by CHAT002 (0.93). Average bank angle ranged from 44° (CHAT006) to 66° (CHAT003; Table 16). In addition to having the steepest banks, CHAT003 also had the least variable bank angles (CV = 0.30; compared to 0.48 [CHAT012] up to 0.62 [CHAT009]). Differences in bank angles between the first-order streams were not statistically significant (Table 15). Average bank vegetation cover ranged from 11% (CHAT006) to 42% (CHAT003; Table 16). CHAT006 had the lowest maximum vegetative cover (50%) as well as the most variability in cover (CV = 1.03; compared to 0.72 [CHAT003] up to 0.89 [CHAT012]). The differences in vegetative cover between CHAT006 (11%) and CHAT002 (34%) as well as CHAT003 (42%) were statistically significant (Table 15). The difference in mean bank vegetative cover between CHAT003 (42%) and CHAT009 (20%) was also statistically significant. The average bank stability score at all five first-order sites was classified as "unstable" (Table 16; see Methods sections for how to interpret bank stability scores). The minimum (best) bank stability scores at CHAT002 (8) and CHAT003 (9) were "at-risk" while the other three sites' minimum scores (10.5 [CHAT012] and 11.50 [CHAT006 and 009]) were classified as "unstable." The maximum (worse) bank stability scores at CHAT003 (15.5) and CHAT012 (15) were 'unstable' while the other three sites had "very unstable" scores (16 [CHAT002 and 009] and 17 [CHAT006]).

Channel slope ranged from 0.0144 m/m (CHAT009) to 0.0341 m/m (CHAT002; Table 5). Reach sinuosity (higher = more sinuous) of the first-order streams ranged from 1.11 (CHAT006) to 1.44 (CHAT012). CHAT002 was almost as sinuous (1.36) as CHAT012 (1.44) while the other two reaches (CHAT003 and CHAT009, both 1.12) had low sinuosity similar to CHAT006. Bankfull area ranged from 0.20 square meters (2.15 square feet [sq ft]; CHAT002) to 1.05 square meters (11.30 sq ft; CHAT009; Table 5). The low bankfull area at CHAT002 is due to the low water depth needed to start inundating the flood chute in the floodplain on river left (Figure 8). Channel-full area ranged from 1.01 square meters (10.87 sq ft; CHAT012) to 3.40 square meters (36.60 sq ft; CHAT003; Table 5). CHAT006 had by far the widest channel-full widths (10.43 meters [34.22 ft] compared to 3.36 meters[CHAT012] up to 6.72 meters [22.05 ft; CHAT002]). Average channel-full area for CHAT006 would have been larger had detailed transect 1 (T1) not incised. While CHAT002 and CHAT003 had similar channel-full widths (6.72 meters and 6.47 meters [22.05 and 21.23 ft], respectively), CHAT003's channel-full depth (1.06 meters [3.48 ft]) due to the entrenched channel is almost twice that of CHAT002's channel-full depth (0.59 meters [1.94 ft]; Table 5).

Paired Sites

Two sets of first-order streams were paired for further analysis (CHAT002 and CHAT003 as well as CHAT009 and CHAT012). T-tests indicated that the differences between CHAT002 and CHAT003 were not significant for the nine variables that were tested (Table 17). Differences between CHAT009 and CHAT012 (Table 18) were statistically significant for active channel width (1.86 meters and 1.38 meters [6.10 and 4.53 ft], respectively) and channel-full height (0.97 meters and 0.63 meters [3.18 and 2.07 ft], respectively).

Table 16. Comparison of reach-scale averaged bank characteristics of the first-order stream sites [m—meters; SD—Standard deviation; CV—Coefficient of variation].

Bank Characteristics	Site Number	n	Min	Mean	Max	SD	CV
Bank Undercut[1] (m)	CHAT002	8	0.08	0.24	0.68	0.23	0.93
	CHAT003	7	0.12	0.25	0.53	0.14	0.58
	CHAT006	4	0.07	0.12	0.20	0.06	0.47
	CHAT009	8	0.06	0.25	0.94	0.30	1.19
	CHAT012	7	0.11	0.24	0.38	0.11	0.46
Bank Angle (°)	CHAT002	22	11.50	52.32	90.00	29.68	0.57
	CHAT003	22	27.10	65.79	96.90	19.63	0.30
	CHAT006	22	10.70	44.44	88.10	24.40	0.55
	CHAT009	22	6.90	47.14	86.50	29.44	0.62
	CHAT012	22	14.50	56.70	89.20	27.17	0.48
Vegetation Cover (%)	CHAT002	22	0.00	34.09	90.00	29.30	0.86
	CHAT003	22	5.00	42.27	90.00	30.34	0.72
	CHAT006	22	0.00	11.14	50.00	11.44	1.03
	CHAT009	22	5.00	19.77	60.00	16.44	0.83
	CHAT012	22	0.00	31.36	90.00	27.95	0.89
Bank Stability[2]	CHAT002	22	8.00	12.98	16.00	1.87	0.14
	CHAT003	22	9.00	13.05	15.50	1.70	0.13
	CHAT006	22	11.50	13.55	17.00	1.50	0.11
	CHAT009	22	11.50	13.45	16.00	1.19	0.09
	CHAT012	22	10.50	12.80	15.00	1.12	0.09

[1] statistics are based on the transects where feature is present (# in parentheses).

[2] bank stability score rankings: 4–7 stable; 8–10 at-risk; 11–15 unstable; and 16–22 very unstable.

Table 17. Difference in means t-test results comparing CHAT002 and CHAT003. The significance of the differences is indicated by: "–"not significant; "*" p-value <0.05, "**" p-value <0.01, and "***" p-value <0.001 [m—meters; mm—millimeters].

Measurements	n	CHAT002	CHAT003	P-value	Significance
Pebble Count (mm)	100	29.93	39.03	0.103	–
Thalweg Depth (m)	11	0.06	0.09	0.126	–
Thalweg Position (%)	11	43	51	0.408	–
Wetted Width (m)	11	1.52	1.68	0.481	–
Active Channel Width (m)	11	2.03	2.21	0.489	–
Channel-full Width (m)	11	6.78	4.67	0.089	–
Channel-full Height (m)	22	1.02	1.03	0.888	–
Bank Angle (°)	22	52	66	0.084	–
Vegetative Cover (%)	22	34	42	0.368	–

Table 18. Difference in means t-test results comparing CHAT009 and CHAT012. The significance of the differences is indicated by: "– "not significant; "*" p-value <0.05, "**" p-value <0.01, and "***" p-value <0.001 [m—meters; mm—millimeters].

Measurements	n	CHAT009	CHAT012	P-value	Significance
Pebble Count (mm)	100	23.58	22.21	0.663	–
Thalweg Depth (m)	11	0.05	0.05	0.693	–
Thalweg Position (%)	11	46	55	0.425	–
Wetted Width (m)	11	0.97	1.13	0.351	–
Active Channel Width (m)	11	1.86	1.38	0.008	**
Channel-full Width (m)	11	4.67	4.02	0.148	–
Channel-full Height (m)	22	0.97	0.63	< 0.001	***
Bank Angle (o)	22	47	57	0.269	–
Vegetative Cover (%)	22	20	31	0.103	–

Medium-Sized (Second-order) Streams

Reach Descriptions

CHAT004—"Crayfish Creek"

On June 8, 2017, stream survey data were collected at CHAT004. CHAT004 is located along an unnamed second-order stream that was nicknamed "Crayfish Creek" because of a large crayfish that was encountered during the survey. The monitored reach on "Crayfish Creek" is approximately 375 meters (1,230 ft) upstream of its confluence with the Chattahoochee River and downstream of a shopping center on Hwy 20. CHAT004 can be accessed through a right-of-way from private land. The reach that was surveyed was 70 meters (230 ft) long with 7 meters (23 ft) between transects. CHAT004 was paired with CHAT005 because CHAT005's watershed is much more forested (83%) than CHAT004's watershed (39%, Table 19).

"Crayfish Creek" is entrenched and has a few areas of bedrock that influence the reach (Figure 21). An ephemeral drainage near T10 is also influencing the reach and groundwater was actively flowing into the stream near this drainage during the survey. CHAT004's channel is entrenched except for one slightly lower terrace/slumped area near T1 and T2. Between T4 and T10, there are alternating (side) cobble bars. Water surface slope (longitudinal profile) for this section of "Crayfish Creek"' was 0.0114 m/m (Table 20). The longitudinal profile is relatively consistent with only a few sections with higher slope (Figure 22). The detailed transects were surveyed on T1 (BM1), T5 (BM2), and T9 (BM3). Detailed transect 2 (T5) and 3 (T9) are entrenched though their river right banks have lower slopes and are slumping (Figure 23). The flat out-of-channel area on river right on detailed transect 1 (T1) was interpreted as a low terrace because a lower (floodplain) surface was observed immediately downstream. Survey results for CHAT004 can be found in Appendix G.

Table 19. Land use/land cover characteristics from 2011 for the second-order streams at Chattahoochee River NRA (NLCD 2011, Homer et al. 2015).

NLCD Classes (%)	CHAT004	CHAT005	CHAT007	CHAT008	CHAT010	CHAT011	CHAT014
Developed Open & Low	41	8	30	56	69	38	46
Developed Med. & High	15	4	1	7	2	43	1
Forested	39	83	42	33	27	19	52
Grassland	5	2	26	3	2	0	0
Cultivated	0	0	0	0	0	0	0

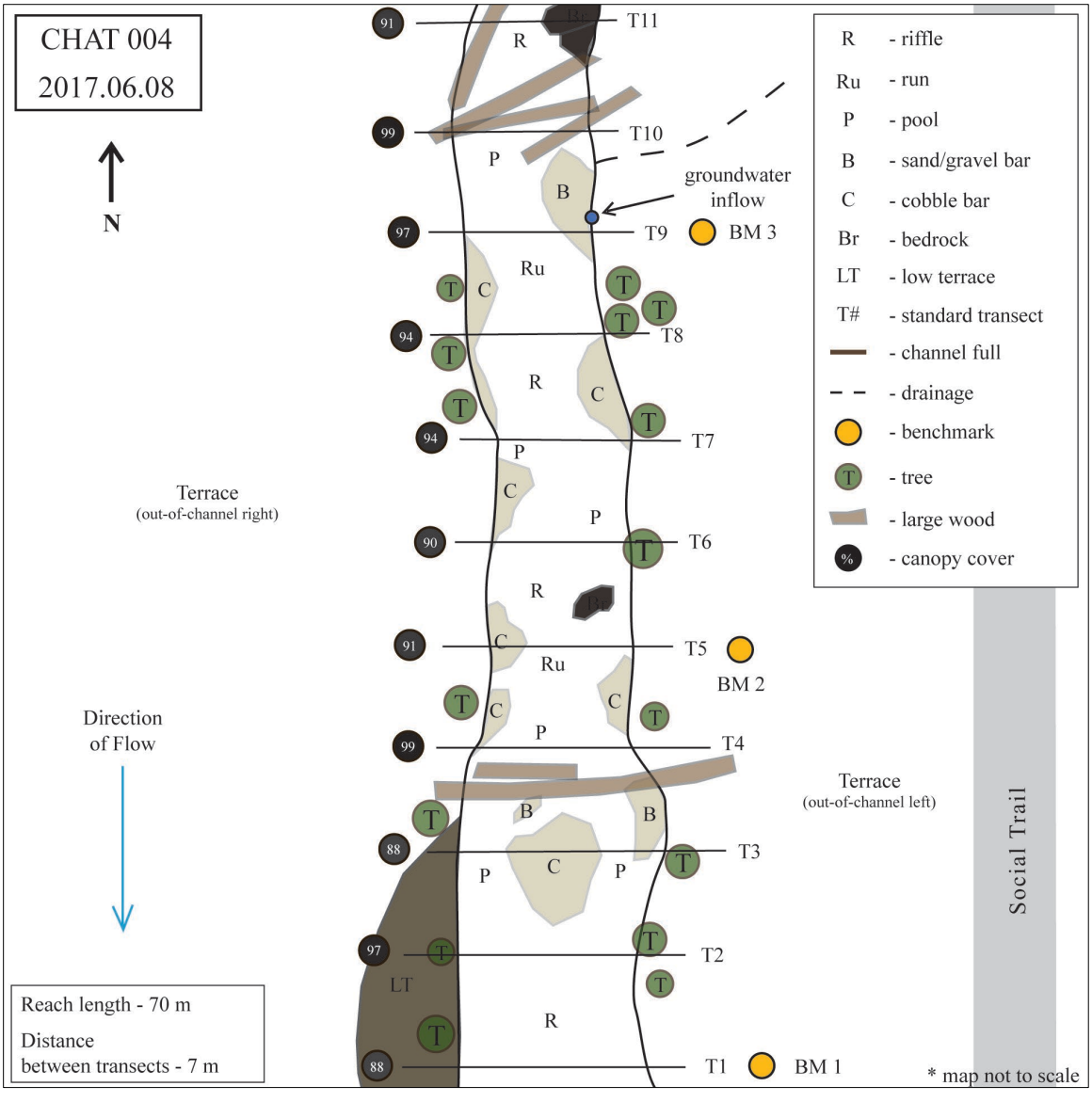


Figure 21. Reach-scale map of CHAT004. Important geomorphic surfaces and in-channel features are labeled to provide a context for the standard and detailed transect information provided in this report. The canopy cover circles are varying shades of grey which indicate the amount of canopy cover at each transect (high and low coverages are labeled).

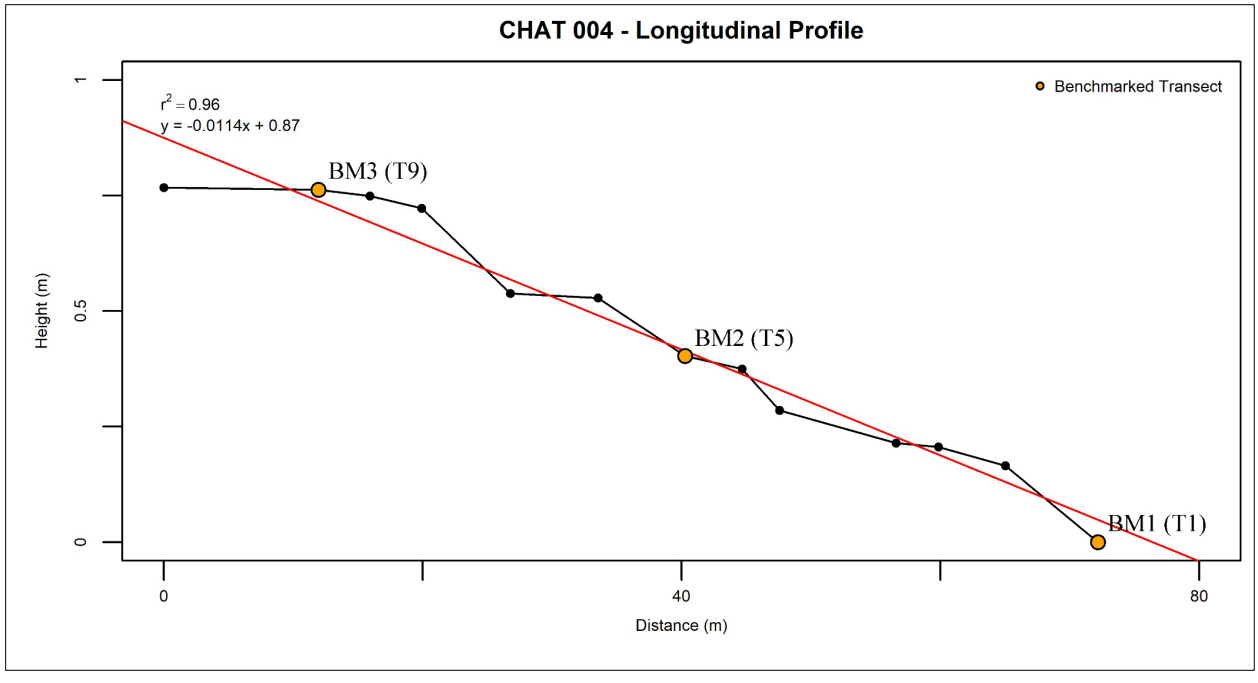


Figure 22. Longitudinal profile for CHAT004. The red line on the graph corresponds to the interpreted slope of the reach. The r^2 value describes the strength of the trend line.

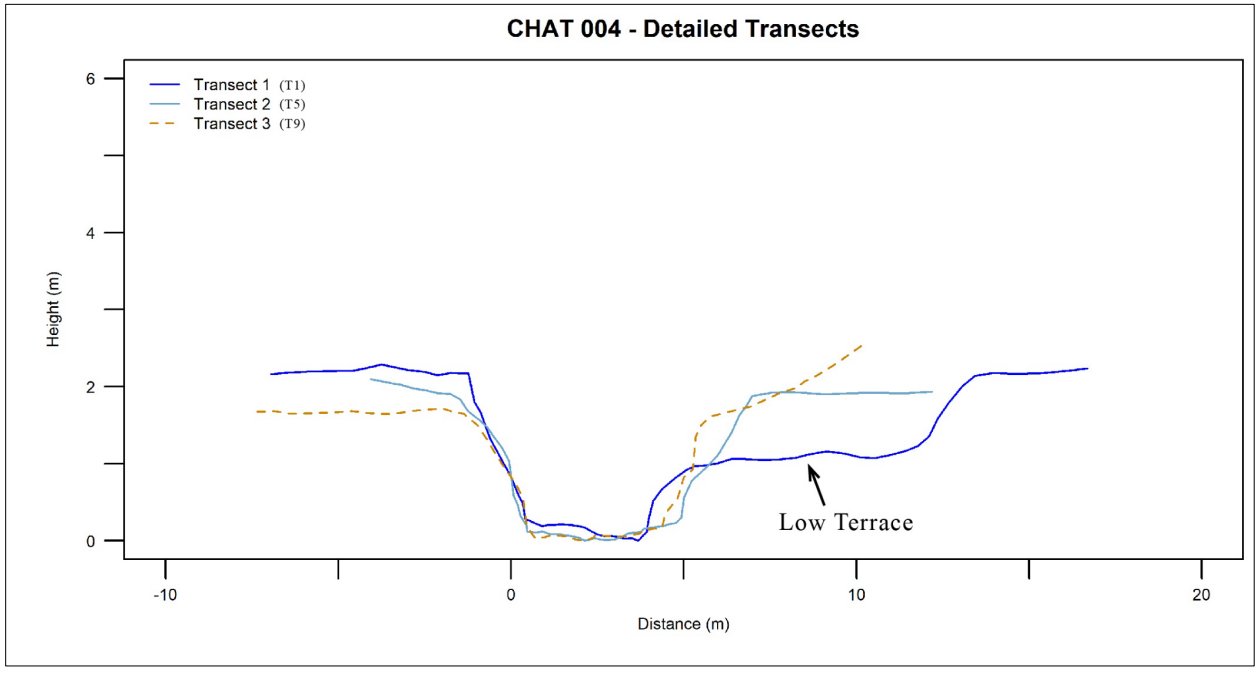


Figure 23. Comparison of the detailed transects at CHAT004. The location of the left channel-full points for each transect are normalized to allow for comparisons between transects.

Table 20. Summary of the results of the detailed transect surveys. Slope and sinuosity measures are based on the water surface and change in slope points taken within the reach. The bankfull and channel-full values are averages of the three detailed transect surveys [m—meters].

Site Number	n[1]	Slope	Sinuosity	n[2]	Bankfull Area (m^2)	Bankfull Width (m)	Bankfull Depth (m)	Channel-full Area (m^2)	Channel-full Width (m)	Channel-full Depth (m)
CHAT004	13	-0.0114	1.02	3	1.89	4.44	0.56	7.37	7.05	1.49
CHAT005	17	-0.0124	1.13	3	1.62	3.83	0.58	4.22	5.31	1.16
CHAT007	14	-0.0049	1.12	3	1.22	3.69	0.50	4.24	7.36	1.01
CHAT008	12	-0.0142	1.10	3	1.34	5.09	0.34	5.04	7.52	0.78
CHAT010	12	-0.0106	1.36	3	2.04	5.05	0.59	6.35	7.88	1.23
CHAT011	11	-0.0087	1.06	3	0.85	4.25	0.28	4.96	7.55	0.96
CHAT014	14	-0.0026	1.50	3	1.15	3.92	0.47	2.84	5.73	0.85

[1] Number of slope measurements

[2] Number of measurements for bankfull and channel-full area, depth, and width

CHAT005—"Egg Creek"

On June 12, 2017, stream survey data were collected at CHAT005. CHAT005 is located along an unnamed second-order stream that was nicknamed "Egg Creek" because fish eggs were found under a rock during the initial assessment of the stream segment. The monitored reach on "Egg Creek" is approximately 190 meters (623 ft) upstream of its confluence with the Chattahoochee River. Social trails run along both sides of the creek, on the terrace that the stream channel is entrenched within (Figure 24).

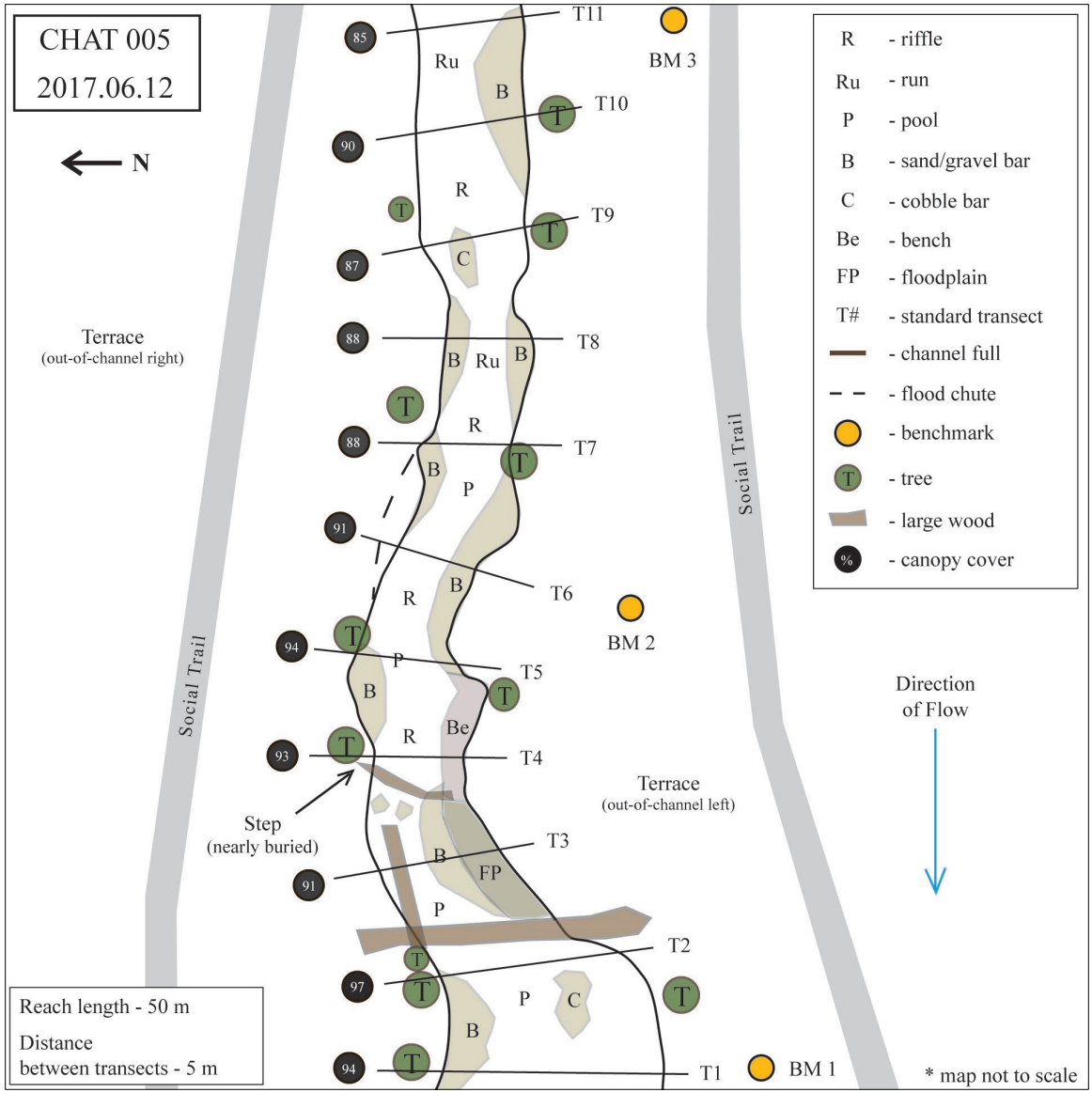


Figure 24. Reach-scale map of CHAT005. Important geomorphic surfaces and in-channel features are labeled to provide a context for the standard and detailed transect information provided in this report. The canopy cover circles are varying shades of grey which indicate the amount of canopy cover at each transect (high and low coverages are labeled).

CHAT005 can be accessed by following the utility right-of-way from the Settles Bridge parking lot to the stream and then walking upstream to the monitored reach. The reach that was surveyed was 50 meters (164 ft) long with 5 meters (16.4 ft) between transects. As explained in CHAT004's description, CHAT005 was paired with CHAT004 because CHAT005's watershed is much more forested (83%) than CHAT004's watershed (39%; Table 19).

"Egg Creek" is slightly entrenched and is primarily influenced by the LWD jam between T2 and T3 (Figure 24). Water surface slope (longitudinal profile) for this section of "Egg Creek"' was 0.0124 m/m (Table 20). The longitudinal profile is relatively consistent with only one section with higher slope (above T1; Figure 25). The detailed transects were surveyed on T1 (BM1), T6 (BM2), and T11 (BM3). None of the detailed transects have developed a floodplain (Figure 26). A point bar has begun to develop on detailed transect 1 (T1) and gravel bars were observed on detailed transects 2 (T6) and 3 (T11). Survey results for CHAT005 can be found in Appendix H.

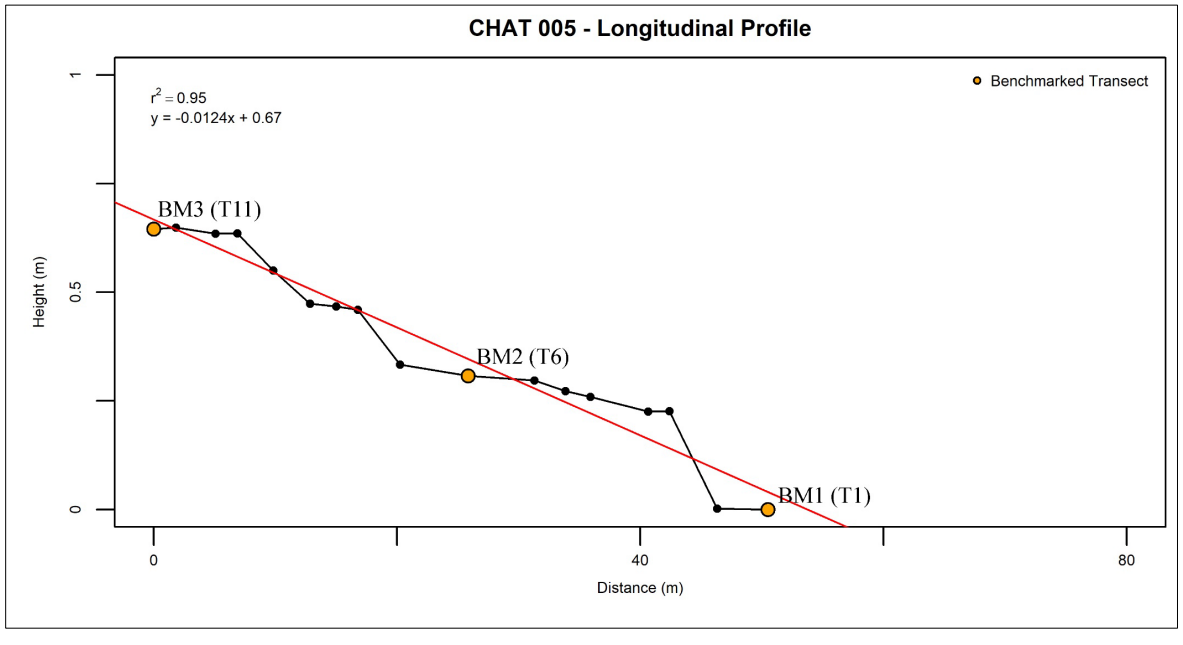


Figure 25. Longitudinal profile for CHAT005. The red line on the graph corresponds to the interpreted slope of the reach. The r^2 value describes the strength of the trend line.

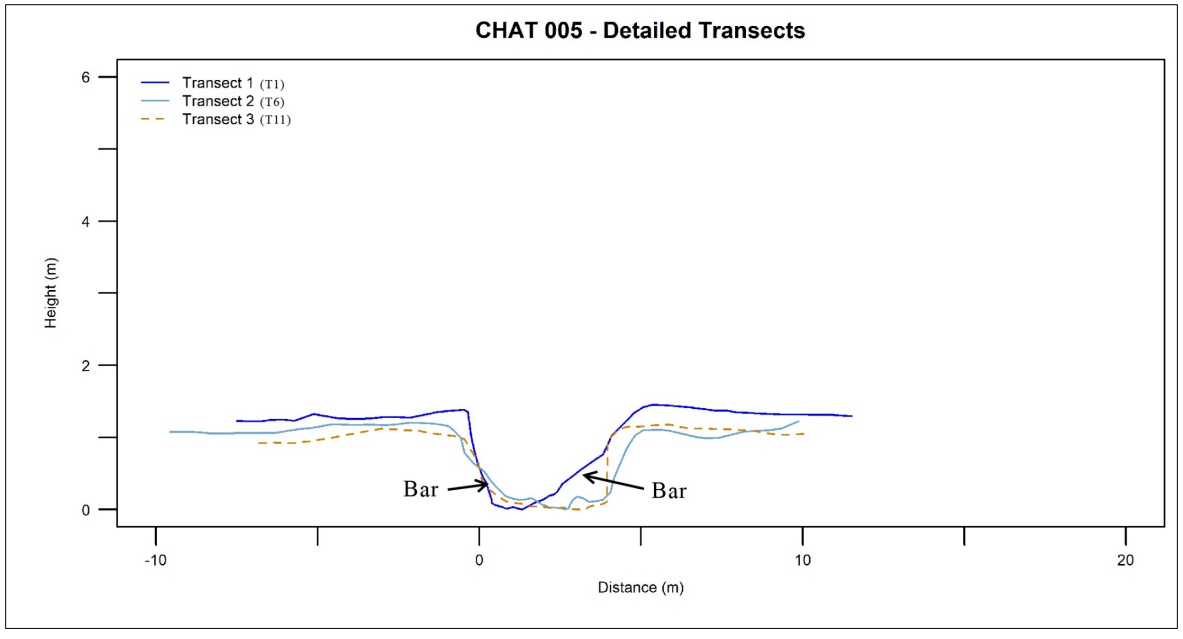


Figure 26. Comparison of the detailed transects at CHAT005. The location of the left channel-full points for each transect are normalized to allow for comparisons between transects.

CHAT007—"Red Tailed Creek"

On June 8, 2017, stream survey data were collected at CHAT007. CHAT007 is located along an unnamed second-order stream that was nicknamed "Red Tail Creek" because of a rather boisterous family of Red Tailed Hawks that made their presence known during one of the trips to the reach. CHAT007 can be accessed by crossing the field near the end of Rogers Bridge road (beyond the locked gate) and then carefully navigating the steep descent down to the channel. CHAT007 is approximately 110 meters (361 ft) upstream of its confluence with the Chattahoochee River. The reach that was surveyed was 50 meters (164 ft) long with 5 meters (16.4 ft) between transects. "Red Tail Creek" was not paired with any of the other sites though it is included in the ANOVA and post-hoc Tukey tests to determine whether it is significantly different from the other second-order streams.

The monitored reach on "Red Tail Creek" is highly entrenched though some small areas of floodplain have developed along the reach (Figure 27). Immediately upstream of the monitored reach, the channel is even more entrenched and steep valley walls encroach directly on to the channel. Water surface slope (longitudinal profile) for this section of "Red Tailed Creek"' was 0.0049 m/m (Table 20). The longitudinal profile is relatively consistent with only one section with higher slope (below T10; Figure 28). The detailed transects were surveyed on T1 (BM1), T6 (BM2), and T11 (BM3). Though a steep hillslope constrains the reach, some small floodplain areas have developed on all three detailed transects (Figure 29). Low terraces were also observed on detailed transects 1 (T1) and 2 (T6). Survey results for CHAT007 can be found in Appendix I.

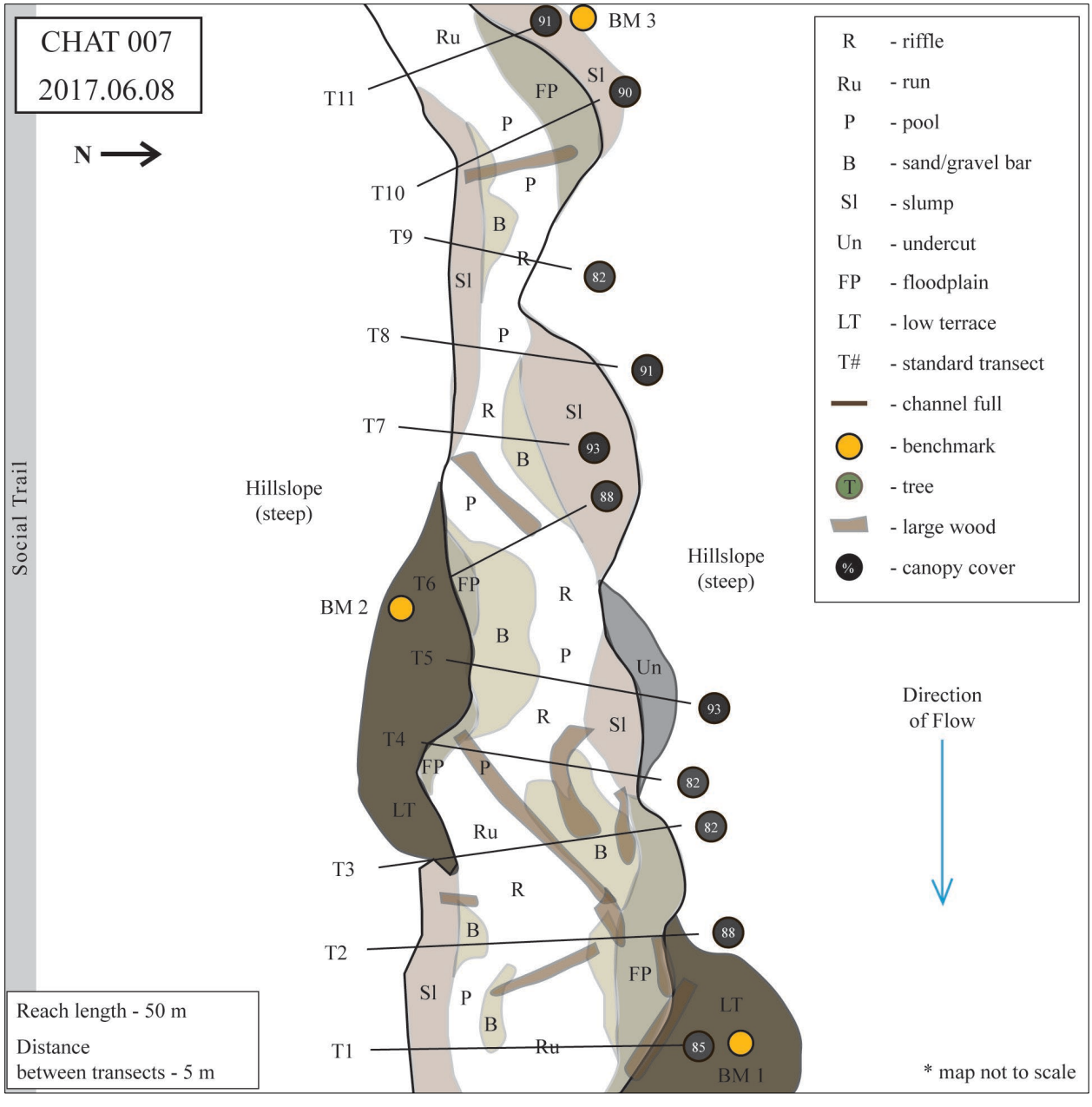


Figure 27. Reach-scale map of CHAT007. Important geomorphic surfaces and in-channel features are labeled to provide a context for the standard and detailed transect information provided in this report. The canopy cover circles are varying shades of grey which indicate the amount of canopy cover at each transect (high and low coverages are labeled).

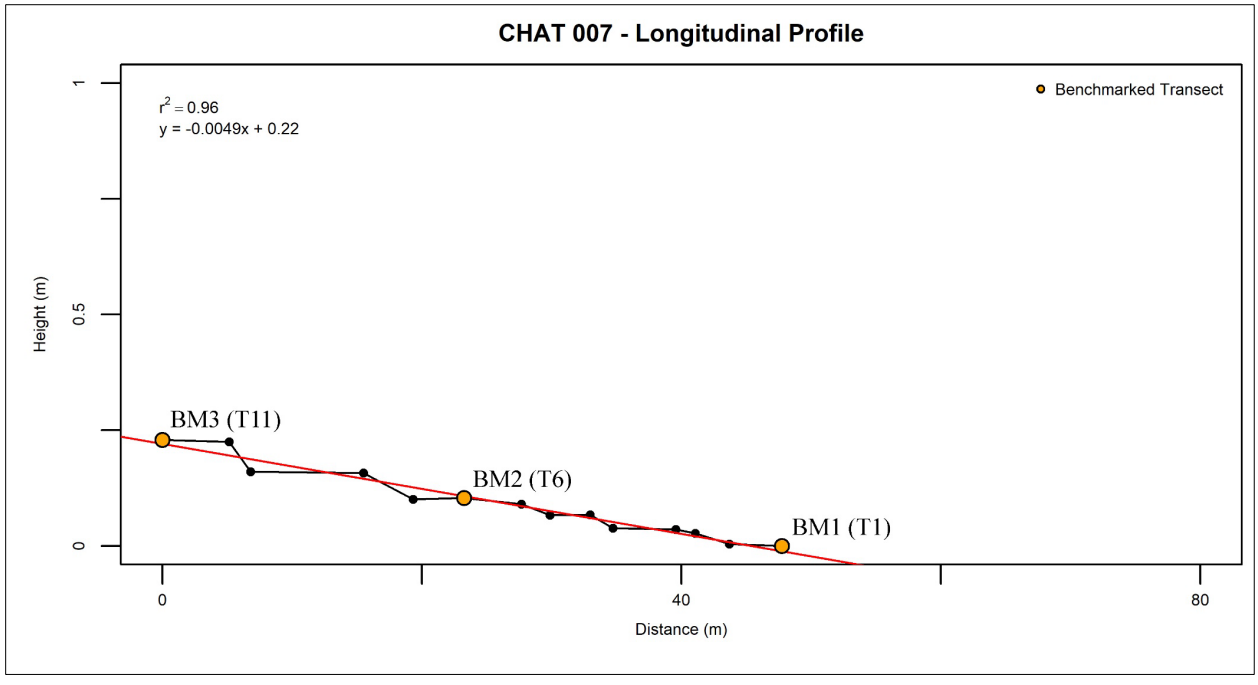


Figure 28. Longitudinal profile for CHAT007. The red line on the graph corresponds to the interpreted slope of the reach. The r^2 value describes the strength of the trend line.

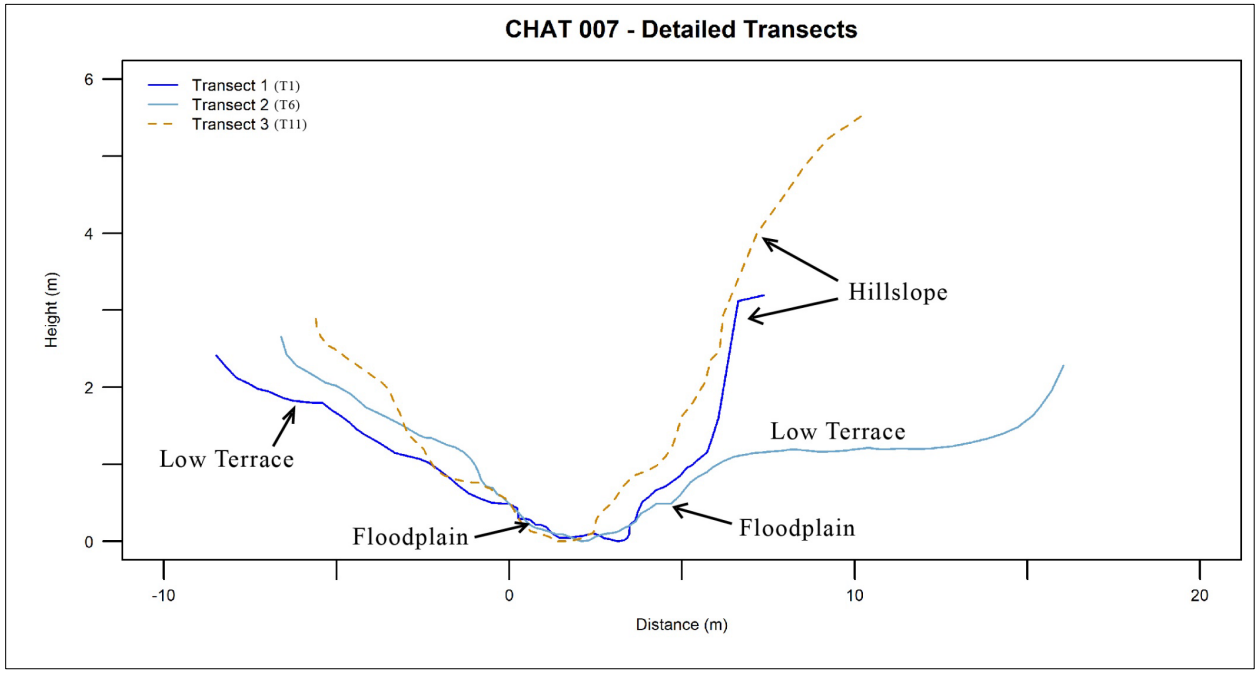


Figure 29. Comparison of the detailed transects at CHAT007. The location of the left channel-full points for each transect are normalized to allow for comparisons between transects.

CHAT008—Mulberry Creek

On June 9, 2017, stream survey data were collected at CHAT008. CHAT008 is located along a portion of Mulberry Creek (a second-order stream downstream of Roswell, Georgia). CHAT008 can be accessed by hiking into the site from the end of the paved road on Hyde Rd N.E. (beyond locked gate). CHAT008 is approximately 700 meters (2,297 ft) upstream of its confluence with the Chattahoochee River. The reach that was surveyed was 50 meters (164 ft) long with 5 meters (16.4 ft) between transects. CHAT008 was paired with CHAT010 because these two streams have similar sized watersheds (1.65 and 2.01 square kilometers [0.64 and 0.78 sq mi], respectively) and similar land use/land cover (Tables 19 and 21).

Table 21. Watershed characteristics for the second-order streams at Chattahoochee River National Recreation Area calculated using the National Elevation Dataset (NED) 10-meter digital elevation model [km—kilometers; m—meters; SD—standard deviation; CV—coefficient of variation].

Basin Characteristic	CHAT004	CHAT005	CHAT007	CHAT008	CHAT010	CHAT011	CHAT014
Drainage Area (km^2)	1.39	0.77	2.35	1.65	2.01	1.01	2.67
NPS Managed Area (km^2)	0.01	0.06	0.08	0.11	0.29	0.14	0.01
NPS Managed Area (%)	0.4%	8%	3%	7%	14%	14%	0.4%
Total Stream Length (km)	1.64	0.95	4.84	2.71	2.72	1.63	4.22
Drainage Density	1.18	1.24	2.06	1.64	1.36	1.62	2.00
Strahler Order	2	2	2	2	2	2	2
Bifurcation Ratio	2.00	2.00	1.25	1.50	1.50	2.00	1.25
Entire Stream Gradient	0.0232	0.0435	0.0160	0.0264	0.0217	0.0328	0.0167
Segment Gradient	0.0135	0.0158	0.0059	0.0155	0.0279	0.0179	0.0145
Slope - Average	8.30	8.38	3.82	6.78	5.39	7.47	8.05
Slope - Std. Dev.	5.40	4.37	3.41	4.64	4.06	5.23	4.88
Slope - CV	0.65	0.52	0.89	0.68	0.75	0.70	0.61
Basin Length (km)	2.32	1.40	3.58	2.85	2.86	2.61	3.33
Basin Shape	0.26	0.39	0.18	0.20	0.25	0.15	0.24
Basin Relief (m)	74.32	71.00	73.55	70.33	70.14	76.09	80.22
Basin Relief Ratio	0.032	0.051	0.021	0.025	0.025	0.029	0.024
Elevation - Std. Dev. (m)	14.41	14.00	16.28	14.62	12.28	17.80	14.45

The monitored reach on Mulberry Creek is only slightly entrenched and some floodplain areas as well as large gravel bars have developed within the reach (Figure 30). Water surface slope (longitudinal profile) for this section of Mulberry Creek was 0.0142 m/m (Table 20). The longitudinal profile shows the riffle pool sequences with the high slope areas between T3 and T6 as well as between T8 and T11 (Figure 31). The detailed transects were surveyed on T1 (BM1), T6 (BM2), and T11 (BM3). Floodplain areas have developed on detailed transects 1 (T1) and 3 (T11; Figure 32). Low terraces were observed on detailed transects 1 (T1) and 2 (T6). Bars have developed on detailed transects 2 (T6) and 3 (T11). Survey results for CHAT008 can be found in Appendix J.

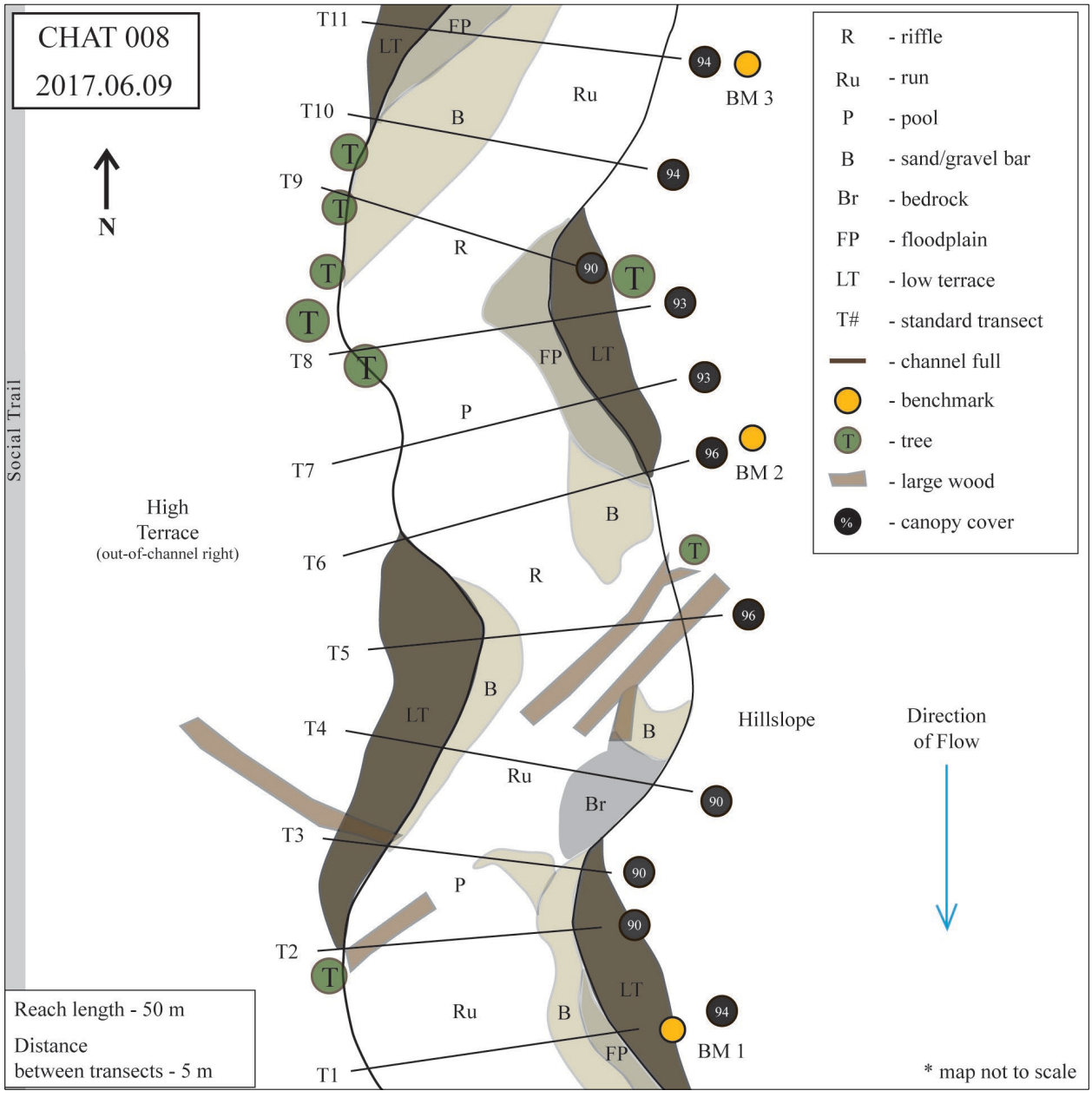


Figure 30. Reach-scale map of CHAT008. Important geomorphic surfaces and in-channel features are labeled to provide a context for the standard and detailed transect information provided in this report. The canopy cover circles are varying shades of grey which indicate the amount of canopy cover at each transect (high and low coverages are labeled).

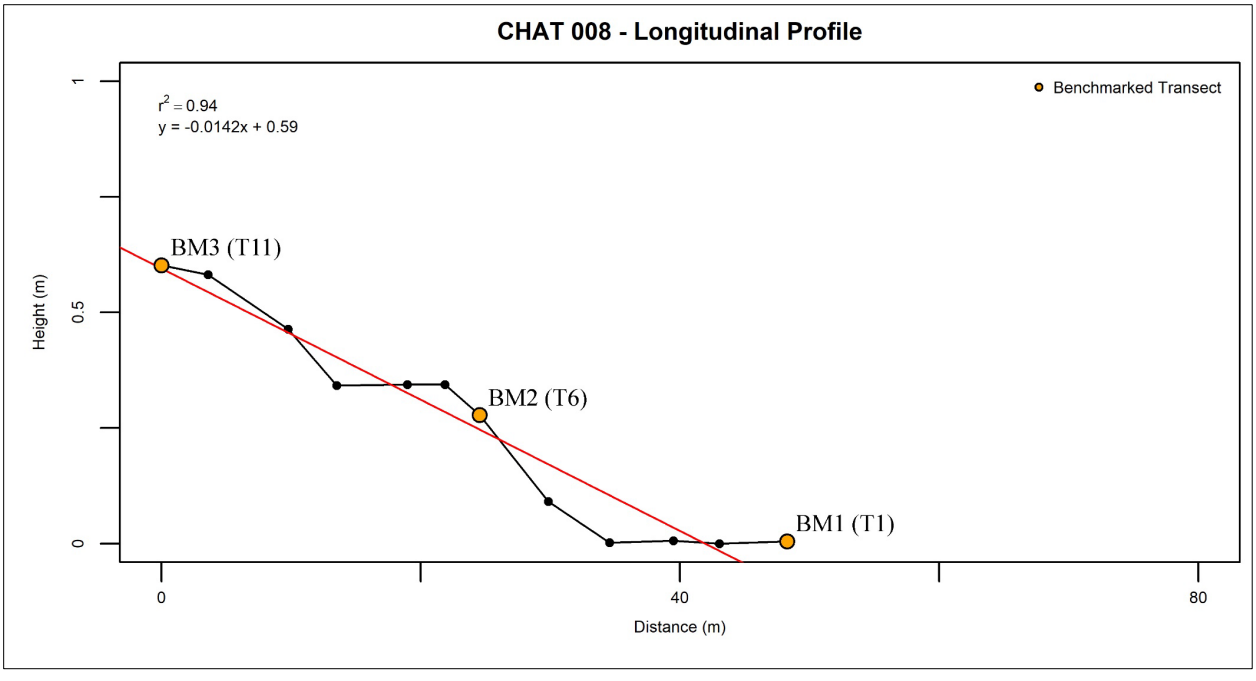


Figure 31. Longitudinal profile for CHAT008. The red line on the graph corresponds to the interpreted slope of the reach. The r^2 value describes the strength of the trend line.

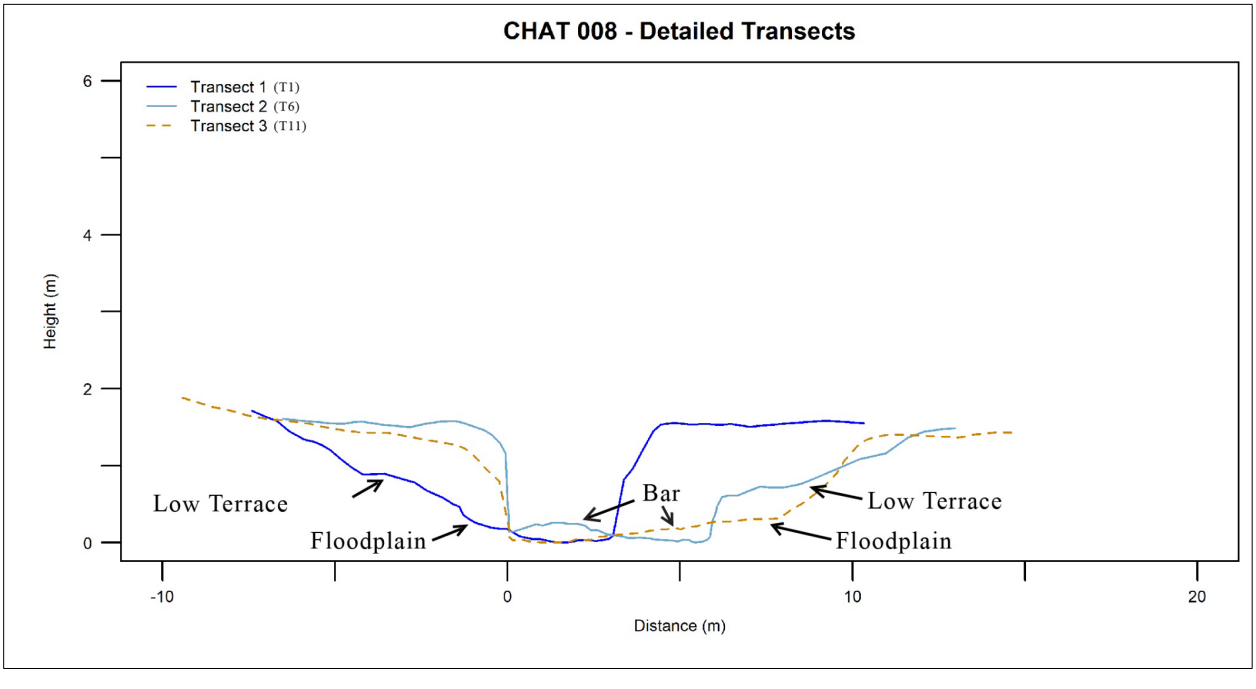


Figure 32. Comparison of the detailed transects at CHAT008. The location of the left channel-full points for each transect are normalized to allow for comparisons between transects.

CHAT010—"Beaver Creek"'

On June 14, 2017, stream survey data were collected at CHAT010. CHAT010 is located along an unnamed second-order stream that was nicknamed "Beaver Creek" because of a beaver dam downstream of the surveyed reach. "Beaver Creek" can be accessed by following the right fork on the trail along Terrell Mill Creek to within approximately 100 meters (328 ft) of the stream. CHAT010 is approximately 240 meters (787 ft) upstream of its confluence with Terrell Mill Creek. The reach that was surveyed was 70 meters (230 ft) long with 7 meters (23 ft) between transects. As explained in CHAT008's description, CHAT010 was paired with CHAT008 because these two streams have similar sized watersheds (Table 21) and similar land use/land cover (Table 19).

The monitored portion of "Beaver Creek" is moderately entrenched though some areas of floodplain have developed (Figure 33). A large tree fall between T4 and T6 is influencing the stream and has caused a lot of LWD to accumulate in a jam. Water surface slope (longitudinal profile) for this section of "Beaver Creek" was 0.0106 m/m (Table 20). The longitudinal profile shows the high slope riffle pool sequence between T5 and T7 (Figure 34). The detailed transects were surveyed on T1 (BM1), T8 (BM2), and T10 (BM3). A floodplain surface has developed on detailed transect 1 (T1) and low terraces were observed on detailed transects 1 and 2 (T8; Figure 35). Survey results for CHAT010 can be found in Appendix K.

CHAT011—Gunby Creek

On June 14, 2017, stream survey data were collected at CHAT011. CHAT011 is located along Gunby Creek (a second-order stream along a sewage right-of-way in the Cochran Shoals unit). Gunby Creek can be accessed by crossing the bridge over Terrell Mill Creek, following the road to the wetland, and then taking the trail that runs alongside the wetland to the site. CHAT011 is approximately 350 meters (1,148 ft) upstream of a wetland. The surveyed reach was 40 meters (131 ft) long with 4 meters (13.1 ft) between transects. CHAT0011 was paired with CHAT0014 because both streams are influenced by upstream areas of bedrock and CHAT011's watershed is much more developed (81%) than CHAT014's watershed (47%; Table 19).

The monitored portion of Gunby Creek has floodplain areas in the downstream portion of the reach (Figure 36). The upstream portion of the reach (on river right) is influenced by bedrock and a steep hillslope. The left bank between T1 and T3 is moderately undercut. Water surface slope (longitudinal profile) for this section of "Beaver Creek" was 0.0087 m/m (Table 20). The longitudinal profile highlights the flat-water pool areas upstream and the higher slope riffle areas downstream of T9 (Figure 37). The detailed transects were surveyed on T1 (BM1), T4 (BM2), and T6 (BM3). Transects upstream of T6 were unsuitable for the detailed transect surveys because of the encroaching hillslope. A floodplain surface was observed on all three detailed transects (Figure 38). Survey results for CHAT011 can be found in Appendix L.

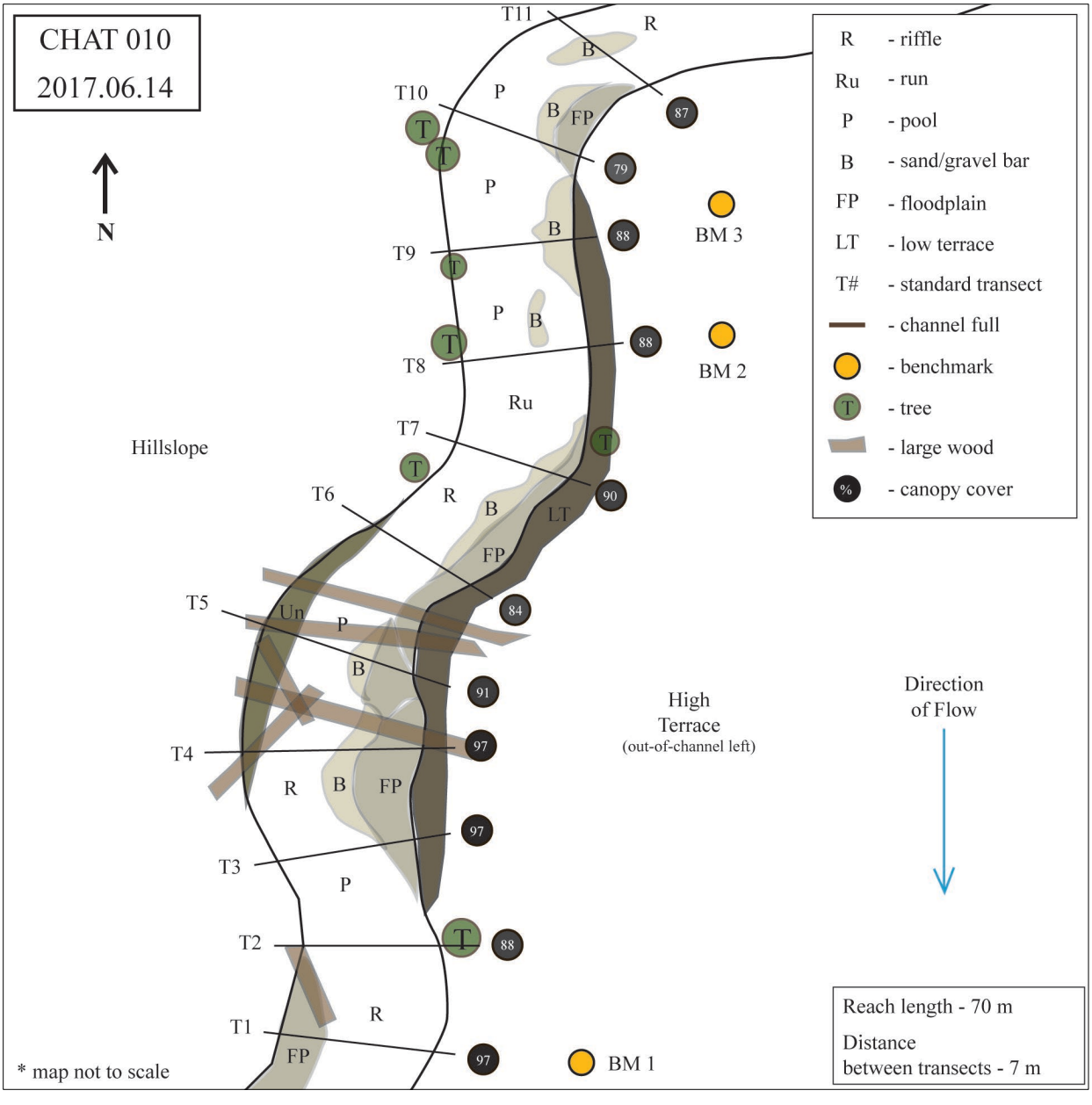


Figure 33. Reach-scale map of CHAT010. Important geomorphic surfaces and in-channel features are labeled to provide a context for the standard and detailed transect information provided in this report. The canopy cover circles are varying shades of grey which indicate the amount of canopy cover at each transect (high and low coverages are labeled).

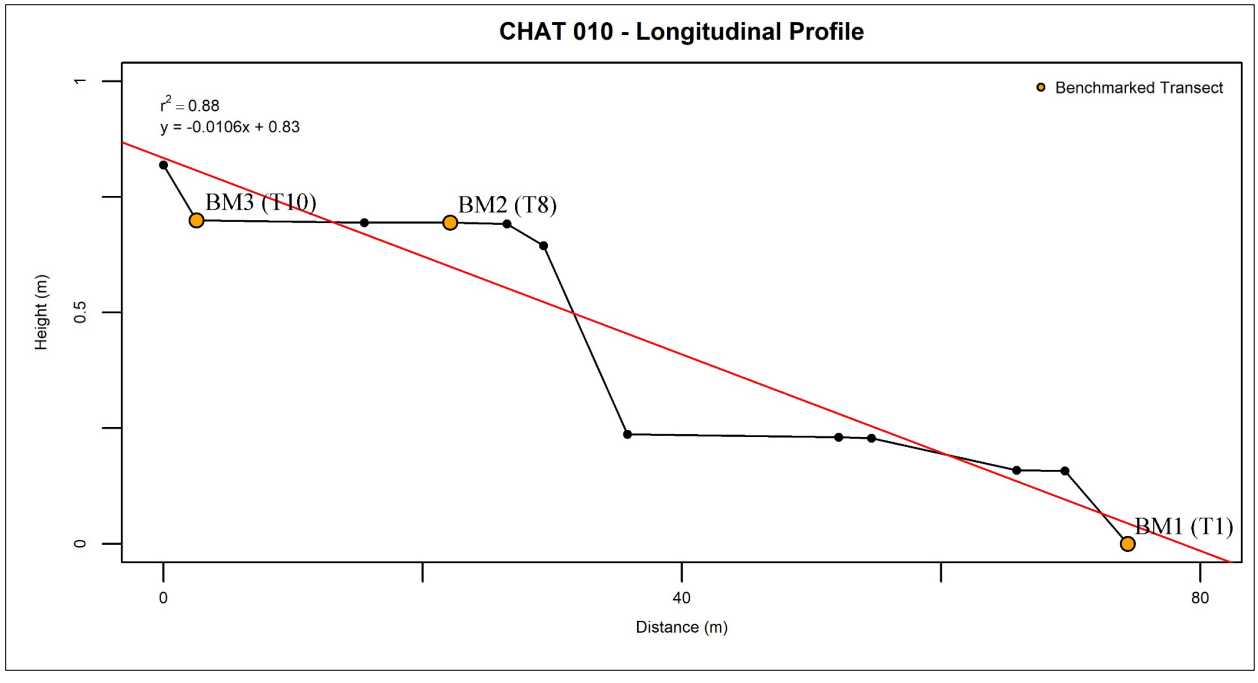


Figure 34. Longitudinal profile for CHAT010. The red line on the graph corresponds to the interpreted slope of the reach. The r^2 value describes the strength of the trend line.

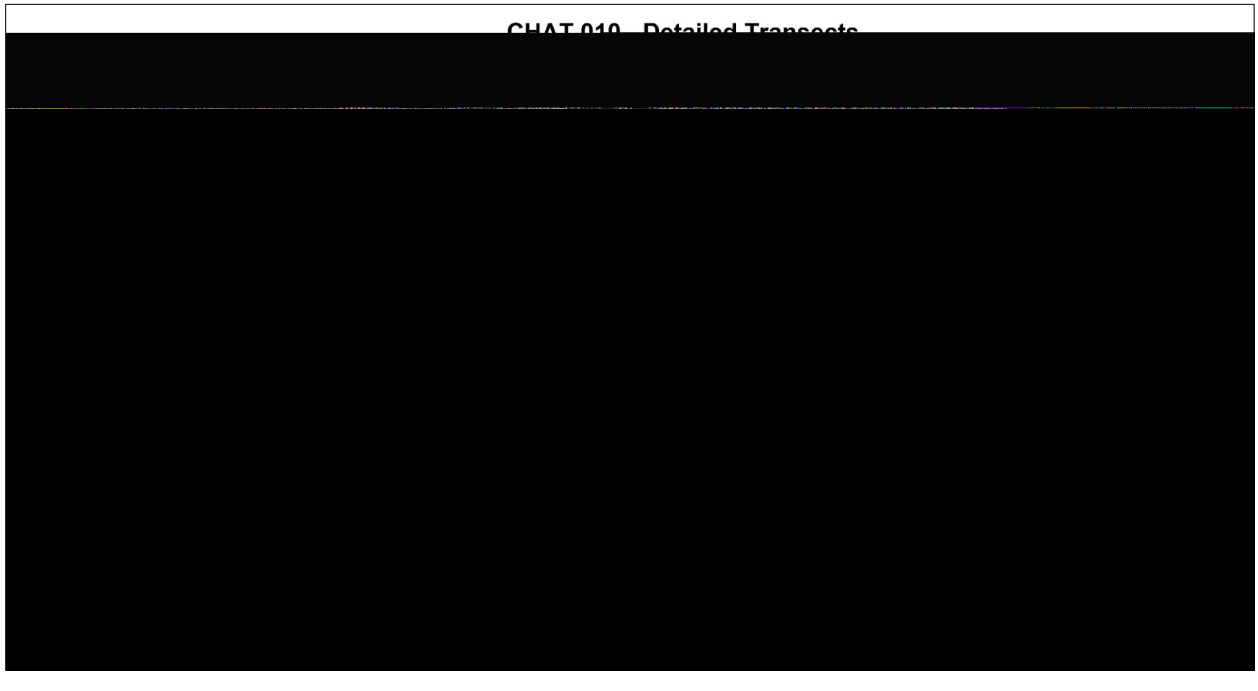


Figure 35. Comparison of the detailed transects at CHAT010. The location of the left channel-full points for each transect are normalized to allow for comparisons between transects.

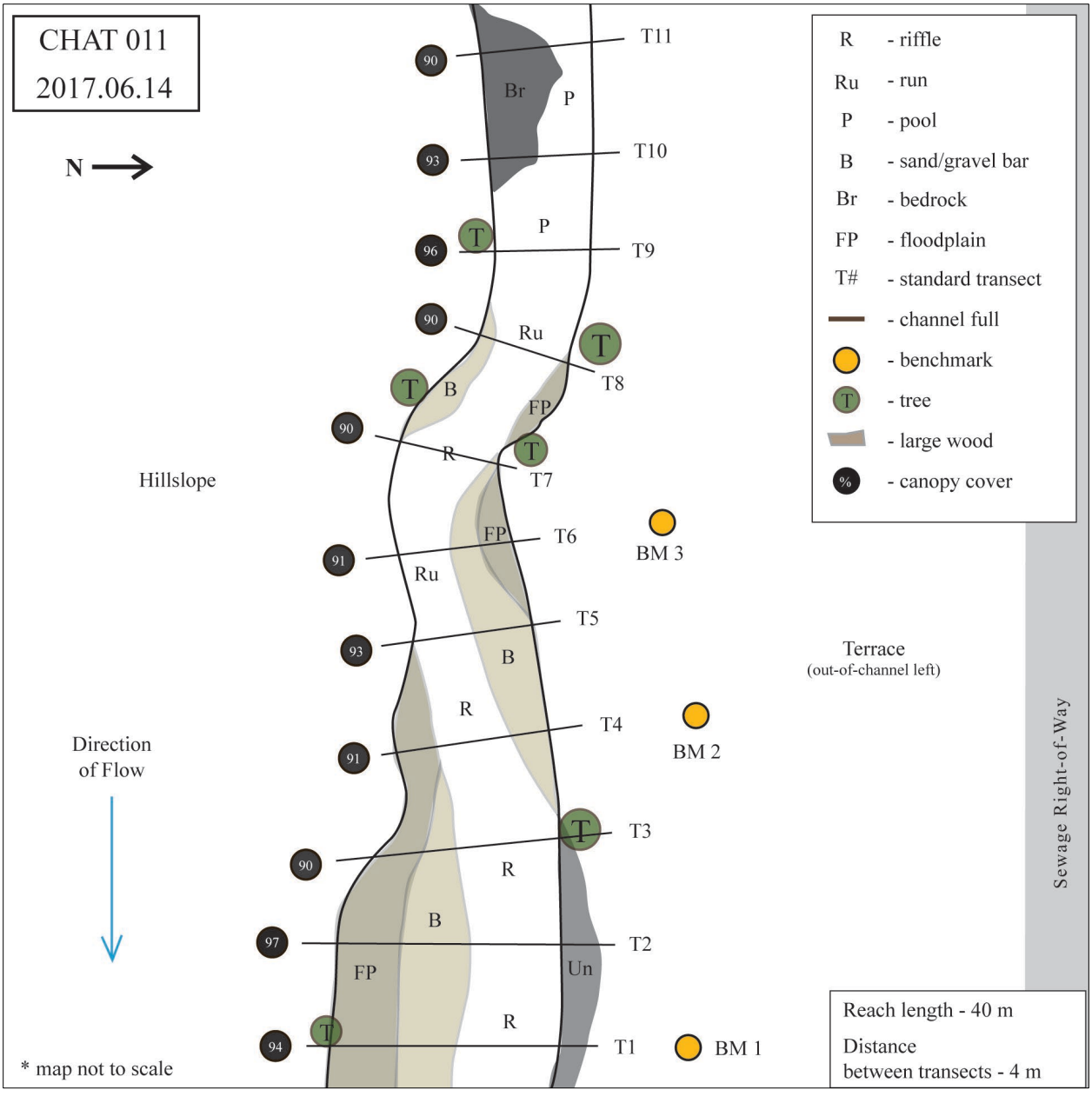


Figure 36. Reach-scale map of CHAT011. Important geomorphic surfaces and in-channel features are labeled to provide a context for the standard and detailed transect information provided in this report. The canopy cover circles are varying shades of grey which indicate the amount of canopy cover at each transect (high and low coverages are labeled).

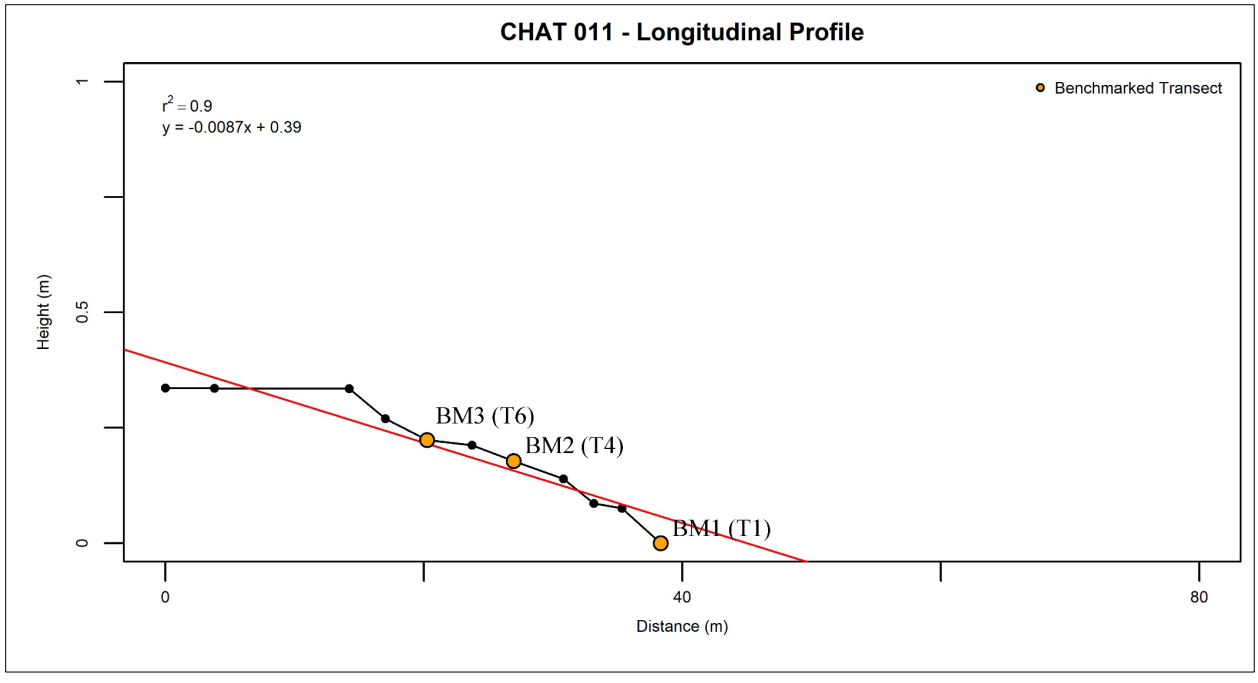


Figure 37. Longitudinal profile for CHAT011. The red line on the graph corresponds to the interpreted slope of the reach. The r^2 value describes the strength of the trend line.

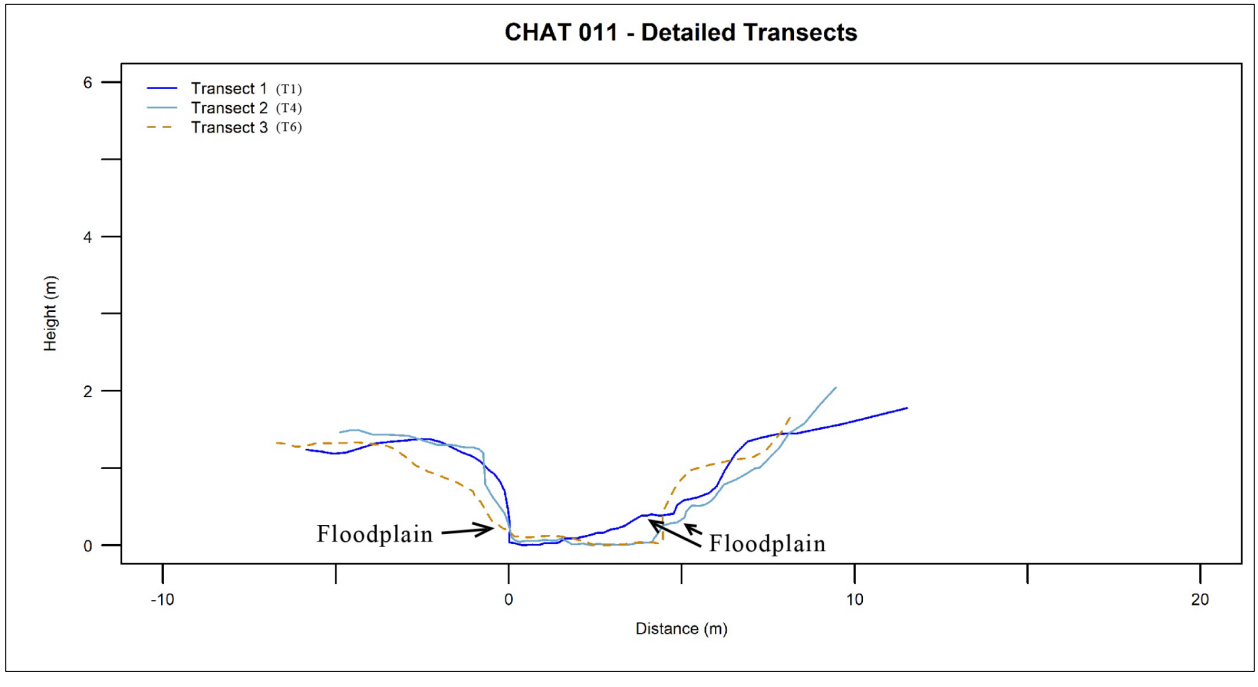


Figure 38. Comparison of the detailed transects at CHAT011. The location of the left channel-full points for each transect are normalized to allow for comparisons between transects.

CHAT014—Whitewater Creek

On June 13, 2017, stream survey data were collected at CHAT014. CHAT014 is located along Whitewater Creek (a second-order stream upstream of a utility right-of-way). Whitewater Creek can be accessed by walking upstream from the Whitewater Creek parking area. The reach that was surveyed was 50 meters (164 ft) long with 5 meters (16.4 ft) between transects. As explained in CHAT011's description, CHAT0014 was paired with CHAT0011 because both streams are influenced by upstream areas of bedrock and CHAT011's watershed is much more developed (81%) than CHAT014's watershed (47%; Table 19).

The monitored portion of CHAT014 is slightly entrenched and two small areas of floodplain have developed (between T8 and T10; Figure 39). Additionally, a flood chute was identified which could bypass the main channel between T4 and T10 during an overbank event. Water surface slope (longitudinal profile) for this section of "Beaver Creek" was 0.0026 m/m (Table 20). The longitudinal profile is relatively consistent, except for two areas with higher slope near T6 and T11 (Figure 40). The detailed transects were surveyed on T1 (BM1), T6 (BM2), and T10 (BM3). A floodplain surface was surveyed on detailed transect 3 (T10) and bars were observed on detailed transects 1 (T1) and 2 (T6; Figure 41). The flood chute between T4 and T10 was also surveyed on the river left side of detailed transect 2 (T6). Survey results for CHAT014 can be found in Appendix M.

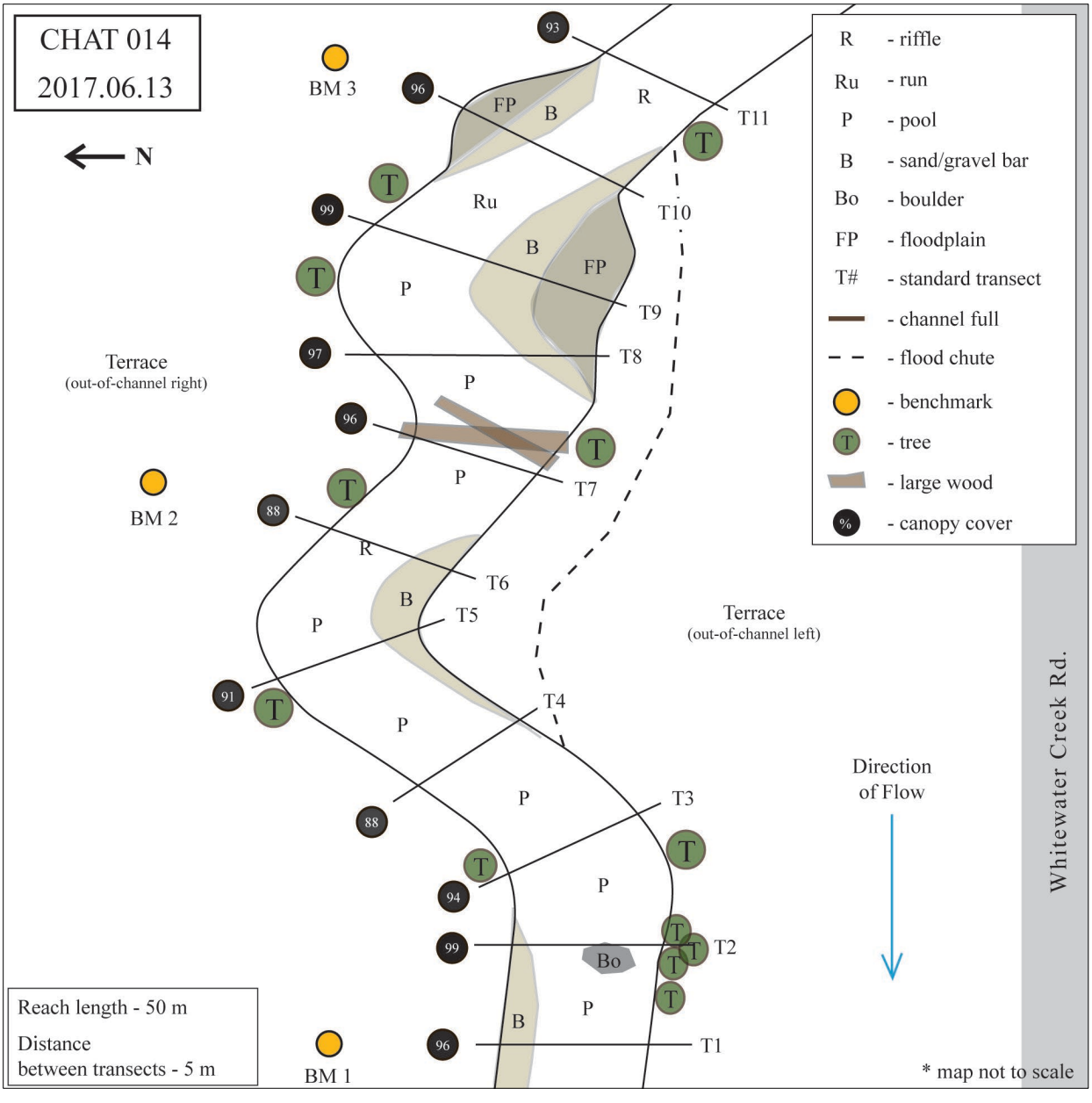


Figure 39. Reach-scale map of CHAT014. Important geomorphic surfaces and in-channel features are labeled to provide a context for the standard and detailed transect information provided in this report. The canopy cover circles are varying shades of grey which indicate the amount of canopy cover at each transect (high and low coverages are labeled).

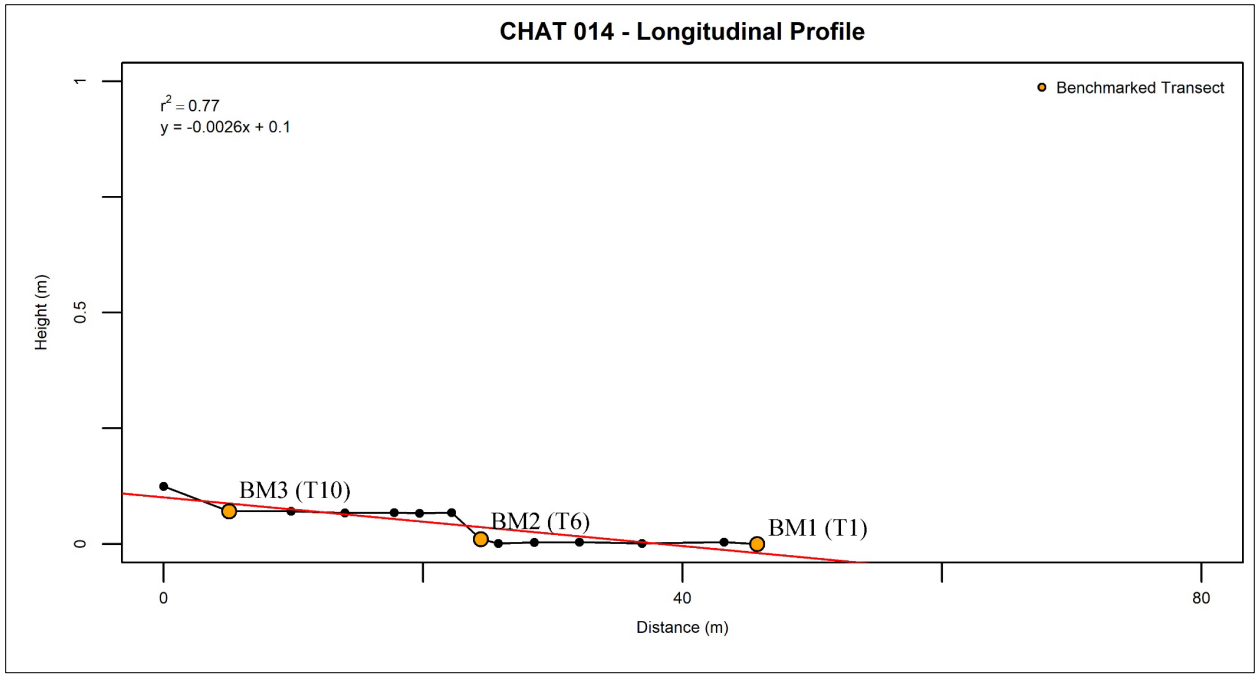


Figure 40. Longitudinal profile for CHAT014. The red line on the graph corresponds to the interpreted slope of the reach. The r^2 value describes the strength of the trend line.

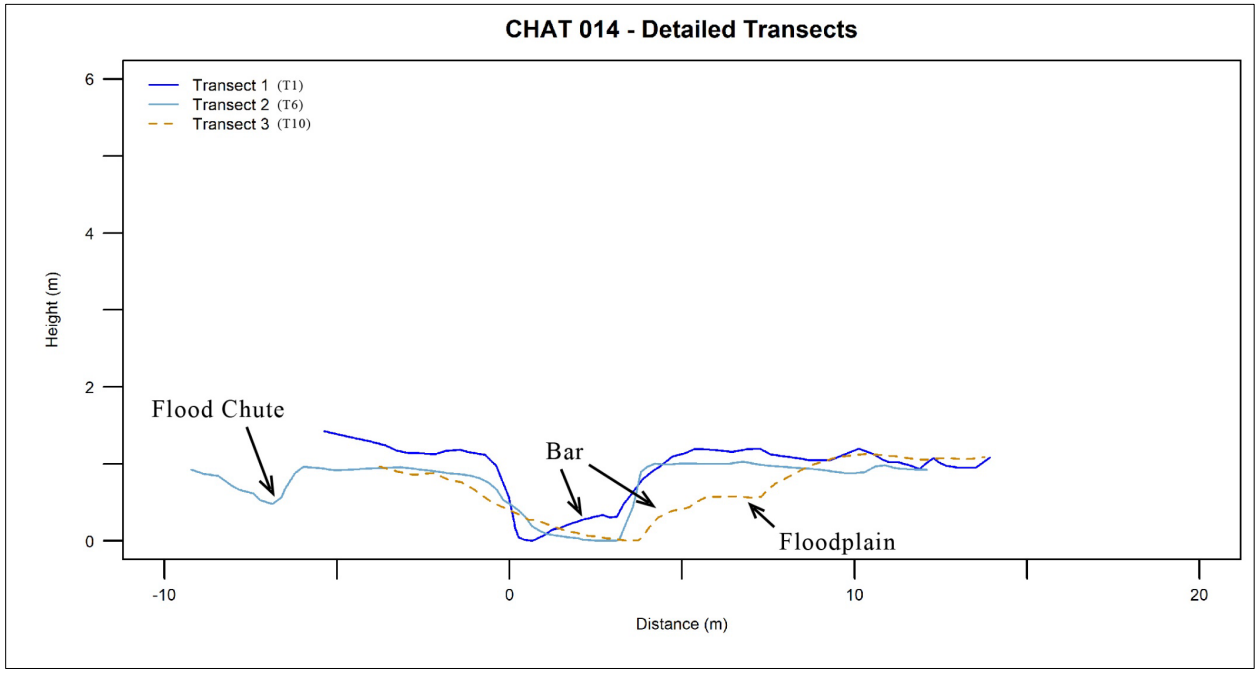


Figure 41. Comparison of the detailed transects at CHAT014. The location of the left channel-full points for each transect are normalized to allow for comparisons between transects.

Basin Characteristics

The second-order watersheds range in size from 0.77 square kilometers (0.30 sq mi; CHAT005) to 2.67 square kilometers (1.03 sq mi; CHAT014; Table 21). Chattahoochee River National Recreation Area manages between 0.4% (CHAT004 and CHAT014) and 14% (CHAT010 and CHAT011) of these watersheds. CHAT007 and CHAT014 have the highest drainage densities of the second-order streams (2.06 km/km^2 and 2.00 km/km^2, respectively). CHAT005 has a higher drainage density than CHAT004 (1.24 km/km^2 versus 1.18 km/km^2) even though CHAT004's watershed (1.39 square kilometers [0.54 sq mi]) is almost twice the size of CHAT005's watershed (0.77 square kilometers [0.30 sq mi]). The bifurcation ratios indicate that CHAT007 and CHAT014 (both 1.25) have a lot more first-order streams in their watersheds than the other second-order streams. CHAT005 has the steepest entire stream gradient (0.0435 m/m) while CHAT007 (0.0160 m/m) and CHAT014 (0.0167 m/m) have the lowest (Table 21). CHAT007 also has the lowest segment gradient (0.0059 m/m) while CHAT010 has the highest segment gradient (0.0279 m/m). CHAT007 has the lowest average watershed slope (3.82°) and the most variable watershed slope (CV = 0.89). Basin shape indicates that the watersheds draining to CHAT007 (0.18) and CHAT011 (0.15) are longer and narrower than the other second-order watersheds (range from 0.20 [CHAT008] to 0.39 [CHAT005]). All seven second-order streams have approximately the same amount of relief (range from 70 meters [230 ft; CHAT008] to 80 meters [262 ft; CHAT014]) though CHAT005 is almost twice as steep (basin relief ratio = 0.051 compared to 0.024 [CHAT014] up to 0.032 [CHAT004]) because its watershed is so much smaller than the other second-order watersheds.

Except for CHAT005, 010, and 011, the second-order watersheds are a mixture of residential or suburban development and forest (Table 19). CHAT005 is mostly forested (83%) while CHAT011 has the least amount of forest cover (19%). CHAT011's watershed has the highest commercial and/or industrial land cover (43% developed medium and high). CHAT010 is mostly residential/suburban (69%) with some (27%) forest cover.

Habitat Characteristics

Except for CHAT007 and 014, the GCU types and distributions for the seven second-order streams were similar (Table 22). Though there were riffles and pools on CHAT007, the highest percentage of GCUs was run habitat (45%). CHAT014 had the highest percent of low energy habitat of all second-order streams, with pools composing on average 76% of the habitat between transects (Table 22). The other five second-order streams had a mixture of riffles, runs, and pools. The pebble count data corroborates the interpretation of differences in energy between the stream reaches. The mean diameter of the pebbles at CHAT007 (8.44 millimeters [0.33 in]) and CHAT014 (13.87 millimeters [0.55 in]) was significantly different (finer) than all other second-order streams (diameters ranged from 34.23 millimeters [1.35 in; CHAT011] up to 50.82 millimeters [2.00 in; CHAT004]; Tables 23 and 24). The stream with the largest mean diameter (CHAT004, 50.82 millimeters [2 in]) was also statistically significantly coarser than the mean diameter of the pebbles at CHAT011 (34.23 mm [1.35 in]).

Table 22. Comparison of GCUs observed in the area between transects for the second-order streams at Chattahoochee River NRA. The data describe the percent coverage of each type of GCU [SD—Standard deviation].

GCU Type	Site Number	Frequency	Max (%)	Mean (%)	SD (%)
Riffle	CHAT004	8	95	39	36
	CHAT005	8	80	44	29
	CHAT007	5	80	24	30
	CHAT008	7	100	41	39
	CHAT010	5	100	30	37
	CHAT011	5	100	42	50
	CHAT014	3	40	8	15
Run	CHAT004	6	80	27	31
	CHAT005	4	75	14	25
	CHAT007	10	70	45	20
	CHAT008	3	70	11	22
	CHAT010	4	100	20	36
	CHAT011	3	100	28	45
	CHAT014	2	100	16	35
Glide	CHAT004	0	0	0	0
	CHAT005	0	0	0	0
	CHAT007	0	0	0	0
	CHAT008	0	0	0	0
	CHAT010	0	0	0	0
	CHAT011	0	0	0	0
	CHAT014	0	0	0	0
Pool	CHAT004	8	100	35	37
	CHAT005	8	100	41	38
	CHAT007	8	65	32	26
	CHAT008	7	100	49	39
	CHAT010	7	100	50	44
	CHAT011	3	100	30	48
	CHAT014	8	100	76	41

Table 22 (continued). Comparison of GCUs observed in the area between transects for the second-order streams at Chattahoochee River NRA. The data describe the percent coverage of each type of GCU [SD—Standard deviation].

GCU Type	Site Number	Frequency	Max (%)	Mean (%)	SD (%)
Step	CHAT004	0	0	0	0
	CHAT005	1	20	2	6
	CHAT007	0	0	0	0
	CHAT008	0	0	0	0
	CHAT010	0	0	0	0
	CHAT011	0	0	0	0
	CHAT014	0	0	0	0

Table 23. Comparison of the particle size distributions of bed sediment (in millimeters [mm]) from the pebble count pebble surveys conducted at the second-order stream sites. The subscripts indicate the percent of the sample that is smaller than the reported diameter.

Statistic (mm)	CHAT004 (n=100)	CHAT005 (n=100)	CHAT007 (n=100)	CHAT008 (n=100)	CHAT010 (n=100)	CHAT011 (n=100)	CHAT014 (n=100)
Min	0.06	0.06	0.06	2.00	2.00	2.00	2.00
D_5	2.00	1.90	1.90	2.00	2.00	3.95	2.00
D_{16}	5.00	2.00	2.00	9.00	6.84	7.84	6.00
D_{50}	37.50	19.50	8.00	34.50	28.00	21.00	13.00
Mean	50.82	37.83	8.44	40.73	41.82	34.23	13.87
D_{84}	93.12	80.48	14.00	76.64	73.00	54.16	20.00
D_{95}	140.50	130.50	19.00	100.50	112.75	102.55	31.00
Max	250.00	178.00	30.00	130.00	190.00	330.00	47.00

Table 24. Significance of the differences in the pebble counts, thalweg depths, and thalweg positions of the second-order streams based on a post-hoc Tukey analysis. The significance of the differences is indicated by: "–"not significant; "*" p-value <0.05, "**" p-value <0.01, and "***" p-value <0.001. F-value and p-value of ANOVA results are reported as footnotes [mm—millimeters; m—meters].

Pairings	n[1]	Pebble Count (mm)	P-value[2]	Sig.	n[3]	Thalweg Depth (m)	P-value[4]	Sig.	Thalweg Position (%)	P-value[5]	Sig.
CHAT005 - CHAT004	100	-12.99	0.127	–	11	-0.060	–	–	26.36	–	–
CHAT007 - CHAT004	100	-42.38	< 0.001	***	11	-0.001	–	–	14.09	–	–
CHAT008 - CHAT004	100	-10.09	0.402	–	11	0.033	–	–	11.36	–	–
CHAT010 - CHAT004	100	-9.00	0.547	–	11	0.124	–	–	28.18	–	–
CHAT011 - CHAT004	100	-16.59	0.016	*	11	-0.002	–	–	7.73	–	–
CHAT014 - CHAT004	100	-36.92	< 0.001	***	11	0.086	–	–	22.27	–	–
CHAT007 - CHAT005	100	-29.39	< 0.001	***	11	0.059	–	–	-12.27	–	–
CHAT008 - CHAT005	100	2.90	0.997	–	11	0.093	–	–	-15.00	–	–
CHAT010 - CHAT005	100	3.99	0.985	–	11	0.184	–	–	1.82	–	–
CHAT011 - CHAT005	100	-3.60	0.991	–	11	0.058	–	–	-18.64	–	–
CHAT014 - CHAT005	100	-23.93	< 0.001	***	11	0.146	–	–	-4.09	–	–
CHAT008 - CHAT007	100	32.29	< 0.001	***	11	0.034	–	–	-2.73	–	–

[1] Number of pebbles

[2] $F(5,100) = 19.329$, $p < 0.001$

[3] Number of measurements for thalweg depth and position

[4] $F(5,11) = 2.176$, $p = 0.055$

[5] $F(5,11) = 2.185$; $p = 0.055$

Table 24 (continued). Significance of the differences in the pebble counts, thalweg depths, and thalweg positions of the second-order streams based on a post-hoc Tukey analysis. The significance of the differences is indicated by: "–"not significant; "*" p-value <0.05, "**" p-value <0.01, and "***" p-value <0.001. F-value and p-value of ANOVA results are reported as footnotes [mm—millimeters; m—meters].

Pairings	n[1]	Pebble Count (mm)	P-value[2]	Sig.	n[3]	Thalweg Depth (m)	P-value[4]	Sig.	Thalweg Position (%)	P-value[5]	Sig.
CHAT010 - CHAT007	100	33.38	< 0.001	***	11	0.125	–	–	14.09	–	–
CHAT011 - CHAT007	100	25.79	< 0.001	***	11	-0.001	–	–	-6.36	–	–
CHAT014 - CHAT007	100	5.46	0.930	–	11	0.087	–	–	8.18	–	–
CHAT010 - CHAT008	100	1.09	> 0.999	–	11	0.091	–	–	16.82	–	–
CHAT011 - CHAT008	100	-6.50	0.851	–	11	-0.035	–	–	-3.64	–	–
CHAT014 - CHAT008	100	-26.83	< 0.001	***	11	0.054	–	–	10.91	–	–
CHAT011 - CHAT010	100	-7.59	0.733	–	11	-0.125	–	–	-20.45	–	–
CHAT014 - CHAT010	100	-27.92	< 0.001	***	11	-0.037	–	–	-5.91	–	–
CHAT014 - CHAT011	100	-20.33	0.001	**	11	0.088	–	–	14.55	–	–

[1] Number of pebbles

[2] $F(5,100) = 19.329$, $p < 0.001$

[3] Number of measurements for thalweg depth and position

[4] $F(5,11) = 2.176$, $p = 0.055$

[5] $F(5,11) = 2.185$; $p = 0.055$

The number of pieces of LWD in the second-order streams ranged from 0 (CHAT011) to 12 (CHAT010; Table 25). Though CHAT010 had the most pieces of LWD, CHAT004 and CHAT007 had the highest volumes of LWD per channel area (0.0067 m^3/m^2 and 0.0063 m^3/m^2, respectively). The LWD at CHAT010 was concentrated in a jam between T4 and T6 and the majority of the pieces of LWD were relatively small (Figure 15). The pieces of LWD at CHAT004 (n = 10) and CHAT007 (n = 11) were very large tree trunks that bridged the channel or served as bank protection. The pieces of LWD at CHAT005 and CHAT008 were also large and were influencing the channel through habitat creation (Figures 24 and 30). Canopy cover at the seven second-order streams ranged from 88% (CHAT007) to 94% (CHAT004 and CHAT014; Table 26). CHAT010 had the most variability in canopy cover (CV = 0.06) while CHAT008 and 011 were the least variable (0.03).

Average thalweg depths ranged from 0.10 meters (0.33 ft; CHAT005) to 0.28 meters (0.92 ft; CHAT010; Table 27). The deepest thalweg was at CHAT008 (0.64 meters [2.10 ft]). Differences in thalweg depth between CHAT005 and CHAT010 were statistically significant (Table 24). Differences in thalweg depth between all other second-order streams were not statistically significant. Variability in thalweg positions (CV) ranged from 0.25 (CHAT010) to 0.60 (CHAT004; Table 27). Differences in thalweg positions were not statistically significant (Table 24).

Table 25. Comparison of the summary statistics for the LWD measured at the second-order stream sites [m—meters].

Statistic	Site Number	n	Length (m)	Diameter (m)	Volume (m^3)
Min	CHAT004	10	2.00	0.10	0.02
	CHAT005	11	1.02	0.09	0.01
	CHAT007	11	1.54	0.09	0.01
	CHAT008	6	1.45	0.12	0.02
	CHAT010	12	1.02	0.10	0.01
	CHAT011	0	–	–	–
	CHAT014	2	3.75	0.15	0.09
Mean	CHAT004	10	3.57	0.23	0.30
	CHAT005	11	2.37	0.16	0.06
	CHAT007	11	3.51	0.23	0.16
	CHAT008	6	3.62	0.20	0.18
	CHAT010	12	2.97	0.19	0.12
	CHAT011	0	–	–	–
	CHAT014	2	4.35	0.23	0.18
Max	CHAT004	10	6.63	0.60	1.61

Statistic	Site Number	n	Length (m)	Diameter (m)	Volume (m^3)
Max (continued)	CHAT005	11	4.18	0.26	0.22
	CHAT007	11	11.15	0.36	0.42
	CHAT008	6	5.53	0.43	0.74
	CHAT010	12	5.70	0.36	0.58
	CHAT011	0	–	–	–
	CHAT014	2	4.95	0.30	0.27
SD	CHAT004	10	1.89	0.16	0.52
	CHAT005	11	1.00	0.06	0.06
	CHAT007	11	2.76	0.08	0.15
	CHAT008	6	1.83	0.12	0.28
	CHAT010	12	1.27	0.08	0.16
	CHAT011	0	–	–	–
	CHAT014	2	0.85	0.11	0.13
Sum	CHAT004	10	–	–	2.96
	CHAT005	11	–	–	0.65
	CHAT007	11	–	–	1.80
	CHAT008	6	–	–	1.06
	CHAT010	12	–	–	1.40
	CHAT011	0	–	–	–
	CHAT014	2	–	–	0.35
Per Channel Area (m^3/m^2)	CHAT004	–	–	–	0.0067
	CHAT005	–	–	–	0.0023
	CHAT007	–	–	–	0.0063
	CHAT008	–	–	–	0.0027
	CHAT010	–	–	–	0.0023
	CHAT011	–	–	–	–
	CHAT014	–	–	–	0.0011

Table 26. Comparison of the variability in canopy cover at the second-order stream sites [SD—Standard deviation; CV—Coefficient of variation].

Site Number	n	Min (%)	Mean (%)	Max (%)	SD (%)	CV
CHAT004	11	88	94	99	4	0.04
CHAT005	11	85	91	97	4	0.04
CHAT007	11	82	88	88	4	0.05
CHAT008	11	90	93	96	2	0.03
CHAT010	11	79	90	97	6	0.06
CHAT011	11	90	92	97	3	0.03
CHAT014	11	88	94	99	4	0.04

Table 27. Comparison of reach-scale averaged thalweg conditions at the second-order stream sites. Depth measurements are in meters and the position is the percent distance from the left bank [m—meters; SD—Standard deviation; CV—Coefficient of variation].[1]

Thalweg Characteristic	Site Number	n	Min	Mean	Max	SD	CV
Depth (m)	CHAT004	11	0.09	0.16	0.34	0.08	0.49
	CHAT005	11	0.04	0.1	0.28	0.07	0.72
	CHAT007	11	0.09	0.16	0.29	0.07	0.42
	CHAT008	11	0.06	0.19	0.64	0.18	0.94
	CHAT010	11	0.08	0.28	0.61	0.17	0.6
	CHAT011	11	0.03	0.16	0.51	0.18	1.11
	CHAT014	11	0.03	0.25	0.48	0.16	0.64
Position[1] (%)	CHAT004	11	5	39	75	24	0.6
	CHAT005	11	25	65	95	22	0.34
	CHAT007	11	10	53	95	28	0.53
	CHAT008	11	10	50	90	24	0.47

[1]position is percent distance from left bank

Table 27 (continued). Comparison of reach-scale averaged thalweg conditions at the second-order stream sites. Depth measurements are in meters and the position is the percent distance from the left bank [m—meters; SD—Standard deviation; CV—Coefficient of variation].[1]

Thalweg Characteristic	Site Number	n	Min	Mean	Max	SD	CV
Position[1] (%) (continued)	CHAT010	11	25	67	90	17	0.25
	CHAT011	11	5	47	90	22	0.48
	CHAT014	11	25	61	95	24	0.39

[1]position is percent distance from left bank

Channel Morphology

Mean wetted width ranged from 1.74 meters (5.71 ft; CHAT007) to 3.30 meters (10.83 ft; CHAT010; Table 28). The difference in mean wetted width between the two reaches with the narrowest wetted widths (CHAT005 [1.94 meters {6.36 ft}] and CHAT007 [1.74 meters {5.71 ft}]) and the two widest wetted width (CHAT004 [3.16 meters or10.37 ft] and CHAT010 [3.30 meters or 10.83 ft]) were statistically significant (Table 29). The differences between the wetted widths at CHAT007 (1.74 meters [5.71 ft]) and CHAT011 (2.96 meters [9.71 ft]) were also statistically significant. CHAT014 had the most variable wetted width (CV = 0.45) while CHAT004 had the least variable wetted width (0.21). Mean active channel width ranged from 2.73 meters (8.96 ft; CHAT005) to 4.21 meters (13.81 ft; CHAT008; Table 28).

Table 28. Comparison of reach-scale averaged width characteristics of the second-order stream sites [m—meters; SD—Standard deviation; CV—Coefficient of variation].

Widths	Site Number	n	Min (m)	Mean (m)	Max (m)	SD (m)	CV
Wetted	CHAT004	11	2.03	3.16	4.13	0.65	0.21
	CHAT005	11	0.85	1.94	2.96	0.69	0.35
	CHAT007	11	1.13	1.74	2.78	0.55	0.31
	CHAT008	11	1.56	2.57	3.63	0.69	0.27
	CHAT010	11	1.46	3.30	4.70	0.90	0.27
	CHAT011	11	1.73	2.96	4.32	0.92	0.31
	CHAT014	11	1.10	2.66	4.61	1.19	0.45
Active Channel	CHAT004	11	2.03	3.93	7.13	1.26	0.32
	CHAT005	11	2.01	2.73	3.65	0.59	0.22
	CHAT007	11	2.02	3.25	4.25	0.72	0.22
	CHAT008	11	3.21	4.21	6.74	1.06	0.25
	CHAT010	11	2.50	4.13	5.46	0.96	0.23

Table 28 (continued). Comparison of reach-scale averaged width characteristics of the second-order stream sites [m—meters; SD—Standard deviation; CV—Coefficient of variation].

Widths	Site Number	n	Min (m)	Mean (m)	Max (m)	SD (m)	CV
Active Channel (continued)	CHAT011	11	3.25	4.04	5.27	0.66	0.16
	CHAT014	11	2.63	3.46	5.51	0.93	0.27
Bankfull	CHAT004	0	–	–	–	–	–
	CHAT005	2	3.16	3.36	3.55	0.28	0.08
	CHAT007	7	2.31	3.66	4.82	0.89	0.24
	CHAT008	6	3.37	4.95	6.38	1.04	0.21
	CHAT010	5	3.41	5.40	8.35	1.97	0.36
	CHAT011	5	4.20	4.61	5.26	0.39	0.09
	CHAT014	3	3.84	4.18	4.45	0.31	0.07
Channel-full	CHAT004	11	4.65	6.35	9.11	1.66	0.26
	CHAT005	11	4.91	5.62	6.44	0.45	0.08
	CHAT007	11	3.50	5.68	7.51	1.23	0.22
	CHAT008	11	5.79	7.96	10.96	1.74	0.22
	CHAT010	11	4.52	8.77	11.78	2.20	0.25
	CHAT011	11	5.55	7.30	9.16	1.30	0.18
	CHAT014	11	4.75	6.37	8.50	1.39	0.22

The differences in mean active channel width between CHAT005 (2.73 meters [8.96 ft]) and the four second-order streams with the widest active channel widths (CHAT004 [3.93 meters or 12.89 ft], CHAT008 [4.21 meters or 13.81 ft], CHAT010 [4.13 meters or 13.55 ft], and CHAT011 [4.04 meters or 13.25 ft]) were statistically significant (Table 29). Mean bankfull width ranged from 3.36 meters (11.02 ft; CHAT005) to 5.40 meters (17.72 ft; CHAT010). No bankfull widths were measured at CHAT004 because no floodplains were surveyed within the surveyed reach. Mean channel-full width ranged from 5.62 meters (18.44 ft; CHAT0005) to 8.77 meters (28.77 ft; CHAT010; Table 28). CHAT005 also had the least variability in channel-full widths (CV = 0.08) out of all second-order streams (which ranged from 0.18 [CHAT011] up to 0.26 [CHAT004]). The differences in mean channel-full width between the widest reaches (CHAT008 [7.96 meters or 26.12 ft] and CHAT010 [8.77 meters or 28.77 ft]) and the narrowest reaches (CHAT005 [5.62 meters {18.44 ft}] and CHAT007 [5.68 meters or 18.64 ft]) were statistically significant (Table 29). Additionally, the differences between channel-full width at CHAT010 (8.77 meters [28.77 ft]) and CHAT004 (6.35 meters [20.83 ft]) as well as CHAT014 (6.37 meters [20.90 ft]) were also statistically significant.

Table 29. Significance of the differences in the wetted widths, active channel widths, and channel-full widths of the second-order streams based on a post-hoc Tukey analysis. The significance of the differences is indicated by: "–"not significant; "*" p-value <0.05, "**" p-value <0.01, and "***" p-value <0.001. F-value and p-value of ANOVA results are reported as footnotes [m—meters].

Pairings	n	Wetted Width (m)	P-value[1]	Sig.	Active Channel Width (m)	P-value[2]	Sig.	Channel-full Width (m)	P-value[3]	Sig.
CHAT005 - CHAT004	11	-1.22	0.015	*	-1.20	0.043	*	-0.73	0.918	–
CHAT007 - CHAT004	11	-1.41	0.003	**	-0.67	0.597	–	-0.67	0.945	–
CHAT008 - CHAT004	11	-0.59	0.633	–	0.29	0.989	–	1.61	0.176	–
CHAT010 - CHAT004	11	0.14	> 0.999	–	0.20	0.998	–	2.42	0.006	**
CHAT011 - CHAT004	11	-0.19	0.998	–	0.12	> 0.999	–	0.95	0.759	–
CHAT014 - CHAT004	11	-0.50	0.789	–	-0.47	0.892	–	0.02	> 0.999	–
CHAT007 - CHAT005	11	-0.19	0.998	–	0.53	0.822	–	0.06	> 0.999	–
CHAT008 - CHAT005	11	0.63	0.553	–	1.49	0.005	**	2.34	0.010	**
CHAT010 - CHAT005	11	1.36	0.004	**	1.40	0.010	**	3.15	< 0.001	***

[1] $F(5,11) = 5.693$, $p < 0.001$

[2] $F(5,11) = 4.019$, $p = 0.002$

[3] $F(5,11) = 6.806$, $p < 0.001$

Table 29 (continued). Significance of the differences in the wetted widths, active channel widths, and channel-full widths of the second-order streams based on a post-hoc Tukey analysis. The significance of the differences is indicated by: "–"not significant; "*" p-value <0.05, "**" p-value <0.01, and "***" p-value <0.001. F-value and p-value of ANOVA results are reported as footnotes [m—meters].

Pairings	n	Wetted Width (m)	P-value[1]	Sig.	Active Channel Width (m)	P-value[2]	Sig.	Channel-full Width (m)	P-value[3]	Sig.
CHAT011 - CHAT005	11	1.02	0.067	–	1.32	0.018	*	1.68	0.141	–
CHAT014 - CHAT005	11	0.72	0.390	–	0.73	0.493	–	0.75	0.907	–
CHAT008 - CHAT007	11	0.82	0.237	–	0.96	0.185	–	2.28	0.013	*
CHAT010 - CHAT007	11	1.55	< 0.001	***	0.87	0.282	–	3.09	< 0.001	***
CHAT011 - CHAT007	11	1.22	0.015	*	0.79	0.403	–	1.62	0.173	–
CHAT014 - CHAT007	11	0.91	0.140	–	0.21	0.998	–	0.69	0.936	–
CHAT010 - CHAT008	11	0.73	0.375	–	-0.09	> 0.999	–	0.81	0.866	–
CHAT011 - CHAT008	11	0.39	0.919	–	-0.17	0.999	–	-0.66	0.946	–
CHAT014 - CHAT008	11	0.09	> 0.999	–	-0.75	0.461	–	-1.59	0.187	–

[1] $F(5,11) = 5.693$, $p < 0.001$

[2] $F(5,11) = 4.019$, $p = 0.002$

[3] $F(5,11) = 6.806$, $p < 0.001$

Table 29 (continued). Significance of the differences in the wetted widths, active channel widths, and channel-full widths of the second-order streams based on a post-hoc Tukey analysis. The significance of the differences is indicated by: "–"not significant; "*" p-value <0.05, "**" p-value <0.01, and "***" p-value <0.001. F-value and p-value of ANOVA results are reported as footnotes [m—meters].

Pairings	n	Wetted Width (m)	P-value[1]	Sig.	Active Channel Width (m)	P-value[2]	Sig.	Channel-full Width (m)	P-value[3]	Sig.
CHAT011 - CHAT010	11	-0.34	0.961	–	-0.08	> 0.999	-	-1.47	0.265	–
CHAT014 - CHAT010	11	-0.64	0.536	–	-0.67	0.606	-	-2.40	0.007	**
CHAT014 - CHAT011	11	-0.30	0.976	–	-0.58	0.744	-	-0.93	0.777	–

[1] $F(5,11) = 5.693$, $p < 0.001$

[2] $F(5,11) = 4.019$, $p = 0.002$

[3] $F(5,11) = 6.806$, $p < 0.001$

Mean minimum bank heights ranged from 1.06 meters (3.48 ft; CHAT014) to 2.62 meters (8.60 ft; CHAT011; Table 30). The maximum minimum bank height (10.54 meters [34.58 ft]) was measured at CHAT011. Minimum bank heights were the most variable at CHAT011 (CV = 1.30) while CHAT005's minimum bank heights were the least variable (CV = 0.21). The reason for the high mean minimum bank heights and high variability at CHAT011 is due to the encroachment of the hillslope on river right in the upstream portions of the reach. No bankfull heights were measured at CHAT004 because no floodplains were surveyed within the reach. The other six second-order sites had mean bankfull heights ranging from 0.39 meters (1.28 ft; CHAT011) to 0.69 meters (2.26 ft; CHAT010; Table 30). Similar to the minimum bank heights, CHAT011 had the highest mean channel-full bank height (3.13 meters [10.27 ft]) and CHAT014 had the lowest mean channel-full bank height (1.13 m [3.71 ft]; Table 30). The other four second-order sites had channel-full heights around 1.5 meters (4.9 ft), though CHAT005 (1.28 meters [4.20 ft]) and CHAT008 (1.36 meters [4.46 ft]) were slightly lower. The difference in mean channel-full height between CHAT011 and all other second-order streams was statistically significant (Table 31). Variability in channel-full heights was relatively low for all streams except for CHAT007 (0.61) and CHAT011 (1.15, due to the influence of high hillslopes on these two reaches; Table 30).

The average depth of the undercuts measured on the second-order streams ranged from 0.15 meters (0.49 ft; CHAT011 and CHAT014) to 0.38 meters (1.25 ft; CHAT005; Table 32). Maximum undercut depth was measured at CHAT005 (0.92 meters [3.02 ft]). CHAT011 had the greatest variability in undercut depth (CV = 0.87); and CHAT005 (0.86) was a close second. Mean bank angles ranged from 49° (CHAT005) to 67° (CHAT004; Table 312). CHAT004 also had the least variable bank angles (CV = 0.23 compared to 0.36 [CHAT007] up to 0.63 [CHAT010]). Differences in mean bank angle between the second-order streams were not statistically significant (Table 31). Mean bank vegetation cover ranged from 15% (CHAT007) to 41% (CHAT011; Table 32). In terms of variability, the opposite was true, CHAT007 was the most variable (CV = 1.37) and CHAT011 was the least variable (CV = 0.57). The differences in mean vegetative cover between CHAT007 (15%) compared to CHAT004 (40%), CHAT008 (37%), and CHAT011 (41%) were statistically significant (Table 31). The mean bank stability scores for all seven second-order sites were classified as 'unstable' (12.4 [CHAT010] up to 13.8 [CHAT014]; Table 32; see Methods sections for how to interpret bank stability scores). The minimum (best) bank stability scores for all second-order streams were "at-risk" (8.0 [CHAT010] up to 10.5 [CHAT004 and 005]). The maximum (worst) bank stability scores at CHAT005 (15.5) and CHAT010 (15.0) were "unstable" while the other five streams had "very unstable" bank scores (ranging from 16.0 [CHAT008 and 014] up to 17.5 [CHAT011]).

Table 30. Comparison of reach-scale averaged bank heights of the second-order stream sites [m—meters; SD—Standard deviation; CV—Coefficient of variation].

Bank Heights	Site Number	n	Min	Mean	Max	SD	CV
Bank Height[1,2] (m)	CHAT004	22	0.84	1.67	2.23	0.45	0.27
	CHAT005	22	0.57	1.22	1.59	0.26	0.21
	CHAT007	22	0.37	1.37	4.30	0.99	0.72
	CHAT008	22	0.38	1.21	1.95	0.47	0.39
	CHAT010	22	0.52	1.31	1.94	0.40	0.31
	CHAT011	22	0.33	2.62	10.54	3.40	1.30
	CHAT014	22	0.43	1.06	1.47	0.29	0.28
Bankfull Height[1,3] (m)	CHAT004	0	–	–	–	–	–
	CHAT005	2	0.57	0.58	0.59	0.01	0.02
	CHAT007	7	0.37	0.54	0.78	0.14	0.26
	CHAT008	6	0.38	0.64	1.03	0.27	0.43
	CHAT010	5	0.52	0.69	0.99	0.18	0.26
	CHAT011	5	0.33	0.39	0.53	0.08	0.20
	CHAT014	3	0.43	0.54	0.65	0.11	0.21
Channel-full Height[1] (m)	CHAT004	22	0.84	1.67	2.23	0.45	0.27
	CHAT005	22	1.02	1.28	1.59	0.17	0.13
	CHAT007	22	0.56	1.63	4.30	1.00	0.61
Channel-full Height[1] (m) (continued)	CHAT008	22	0.66	1.36	1.95	0.38	0.28
	CHAT010	22	0.80	1.45	1.94	0.29	0.20
	CHAT011	22	0.59	3.13	10.54	3.59	1.15
	CHAT014	22	0.61	1.13	1.47	0.23	0.20

[1] above thalweg

[2] this height refers to the lowest bank height on either side (bankfull or channel-full)

[3] statistics are based on the transects where feature is present (# in parentheses)

Table 31. Significance of the differences of the channel-full heights, bank angles, and vegetative cover of the second-order streams based on a post-hoc Tukey analysis. The significance of the differences is indicated by: "–"not significant; "*" p-value <0.05, "**" p-value <0.01, and "***" p-value <0.001. F-value and p-value of ANOVA results are reported as footnotes [m—meters].

Pairings	n	Channel-full Height (m)	P-value[1]	Sig.	Bank Angle (°)	P-value[2]	Sig.	Vegetative Cover (%)	P-value[3]	Sig.
CHAT005 - CHAT004	22	-0.38	0.975	–	-18.43	–	–	-12.27	0.539	–
CHAT007 - CHAT004	22	-0.04	> 0.999	–	-17.15	–	–	-24.32	0.007	**
CHAT008 - CHAT004	22	-0.30	0.993	–	-11.52	–	–	-2.73	> 0.999	–
CHAT010 - CHAT004	22	-0.22	0.999	–	-17.37	–	–	-10.23	0.736	–
CHAT011 - CHAT004	22	1.46	0.016	*	-8.34	–	–	1.59	> 0.999	–
CHAT014 - CHAT004	22	-0.53	0.882	–	-8.10	–	–	-10.45	0.715	–
CHAT007 - CHAT005	22	0.34	0.985	–	1.27	–	–	-12.05	0.561	–
CHAT008 - CHAT005	22	0.08	> 0.999	–	6.90	–	–	9.55	0.794	–
CHAT010 - CHAT005	22	0.17	> 0.999	–	1.06	–	–	2.05	> 0.999	–
CHAT011 - CHAT005	22	1.84	< 0.001	***	10.09	–	–	13.86	0.386	–
CHAT014 - CHAT005	22	-0.15	> 0.999	–	10.33	–	–	1.82	> 0.999	–
CHAT008 - CHAT007	22	-0.26	0.996	–	5.63	–	–	21.59	0.028	*
CHAT010 - CHAT007	22	-0.18	> 0.999	–	-0.21	–	–	14.09	0.366	–

[1] $F(5,11) = 4.811$, $p < 0.001$

[2] $F(5,11) = 1.435$, $p = 0.205$

[3] $F(5,11) = 3.497$, $p = 0.003$

Table 31 (continued). Significance of the differences of the channel-full heights, bank angles, and vegetative cover of the second-order streams based on a post-hoc Tukey analysis. The significance of the differences is indicated by: "–"not significant; "*" p-value <0.05, "**" p-value <0.01, and "***" p-value <0.001. F-value and p-value of ANOVA results are reported as footnotes [m—meters].

Pairings	n	Channel-full Height (m)	P-value[1]	Sig.	Bank Angle (°)	P-value[2]	Sig.	Vegetative Cover (%)	P-value[3]	Sig.
CHAT011 - CHAT007	22	1.50	0.012	*	8.82	–	–	25.91	0.003	**
CHAT014 - CHAT007	22	-0.49	0.914	–	9.05	–	–	13.86	0.387	–
CHAT010 - CHAT008	22	0.08	> 0.999	–	-5.85	–	–	-7.50	0.924	–
CHAT011 - CHAT008	22	1.76	0.001	**	3.19	–	–	4.32	0.995	–
CHAT014 - CHAT008	22	-0.23	0.998	–	3.42	–	–	-7.73	0.913	–
CHAT011 - CHAT010	22	1.68	0.003	**	9.03	–	–	11.82	0.584	–
CHAT014 - CHAT010	22	-0.31	0.991	-	9.27	–	–	-0.23	> 0.999	–
CHAT014 - CHAT011	22	-1.99	< 0.001	***	0.24	–	–	-12.05	0.561	–

[1] $F(5,11) = 4.811$, $p < 0.001$

[2] $F(5,11) = 1.435$, $p = 0.205$

[3] $F(5,11) = 3.497$, $p = 0.003$

Table 32. Comparison of reach-scale averaged bank characteristics of the second-order stream sites [m—meters; SD—Standard deviation; CV—Coefficient of variation].

Bank Characteristics	Site Number	n	Min	Mean	Max	SD	CV
Bank Undercut[1] (m)	CHAT004	13	0.11	0.20	0.41	0.09	0.44
	CHAT005	8	0.14	0.38	0.92	0.33	0.86
	CHAT007	3	0.11	0.17	0.27	0.09	0.51
	CHAT008	8	0.07	0.24	0.58	0.19	0.78
	CHAT010	7	0.07	0.27	0.52	0.16	0.59
	CHAT011	7	0.05	0.15	0.42	0.13	0.87
	CHAT014	9	0.05	0.15	0.27	0.08	0.52
Bank Angle (°)	CHAT004	22	33.90	67.29	92.40	15.19	0.23
	CHAT005	22	13.20	48.86	104.60	27.09	0.55
	CHAT007	22	21.70	50.14	82.20	18.25	0.36
	CHAT008	22	10.60	55.77	90.00	27.64	0.50
	CHAT010	22	8.80	49.92	89.90	31.33	0.63
	CHAT011	22	7.70	58.95	98.80	30.55	0.52
	CHAT014	22	9.40	59.19	90.90	28.63	0.48
Vegetation Cover (%)	CHAT004	22	0.00	39.77	95.00	26.34	0.66
	CHAT005	22	0.00	27.50	50.00	17.03	0.62
	CHAT007	22	0.00	15.45	90.00	21.21	1.37
	CHAT008	22	5.00	37.05	80.00	23.89	0.64
	CHAT010	22	5.00	29.55	70.00	20.81	0.70
	CHAT011	22	5.00	41.36	80.00	23.71	0.57
	CHAT014	22	0.00	29.32	70.00	22.64	0.77
Bank Stability[2]	CHAT004	22	10.50	13.23	17.00	1.65	0.12
	CHAT005	22	10.50	12.84	15.50	1.31	0.10
	CHAT007	22	9.00	12.86	16.50	1.83	0.14
	CHAT008	22	9.00	13.43	16.00	1.61	0.12
	CHAT010	22	8.00	12.36	15.00	2.38	0.19
	CHAT011	22	9.00	12.52	17.50	2.33	0.19
	CHAT014	22	9.00	13.77	16.00	1.78	0.13

[1]statistics are based on the transects where feature is present (# in parentheses)

[2]bank stability score rankings: 4–7 stable; 8–10 at-risk; 11–15 unstable; and 16–22 very unstable

Channel slope ranged from 0.0026 m/m (CHAT014) to 0.0142 m/m (CHAT008; Table 20). Reach sinuosity of the second-order streams ranged from 1.02 (CHAT004) to 1.50 (CHAT014). CHAT010 was almost as sinuous (1.36) as CHAT014 (1.50) while CHAT011 (1.06) was nearly as straight as CHAT014 (1.02). The other three second-order streams were only slightly sinuous (value approximately 1.11). Bankfull area ranged from 0.85 square meters (9.15 sq ft; CHAT011) to 2.04 square meters (21.96 sq ft; CHAT010; Table 20). Channel-full area ranged from 2.84 square meters (30.57 sq ft; CHAT014) to 7.37 square meters (79.33 sq ft; CHAT004). The large channel-full area at CHAT004 is due to the entrenched nature of the stream and the high channel-full bank heights.

Paired Sites

Three sets of second-order streams were paired for further analysis (CHAT004 and CHAT005, CHAT008 and CHAT010, and CHAT011 and CHAT014). T-tests indicated that the differences between CHAT004 and CHAT005 were significant for six of the nine variables that were tested (Table 33). Differences in thalweg depth, channel-full widths, and vegetative cover were not statistically significant. The differences in wetted width (3.16 and 1.94 meters [10.37 and 6.36 ft]) and channel-full heights (1.67 and 1.28 meters [5.48 and 4.20 ft]) were highly significant, differences in bank angle (67% and 49%) were moderately significantly, and differences in the other three variables were only marginally significant.

The difference in mean wetted width between CHAT008 (2.57 meters [8.43 ft]) and CHAT010 (3.30 meters [10.83 ft]) was marginally statistically significant (Table 34). Differences between the other eight variables at CHAT008 and CHAT010 were not significant. The mean pebble count and channel-full heights between CHAT011 (34.23 millimeters and 3.13 meters [1.35 in and 10.27 ft]) and CHAT014 (13.90 millimeters and 1.13 meters [0.55 in and 3.71 ft]) were statistically significant (Table 35). The large difference between mean pebble diameters was strongly significant while the difference in channel-full heights was only marginally significant.

Table 33. Difference in means t-test results comparing CHAT004 and CHAT005. The significance of the differences is indicated by: "–"not significant; "*" p-value <0.05, "**" p-value <0.01, and "***" p-value <0.001 [mm—millimeters; m—meters].

Measurements	n	CHAT004	CHAT005	P-value	Significance
Pebble Count (mm)	100	50.82	37.83	0.047	*
Thalweg Depth (m)	11	0.16	0.10	0.079	–
Thalweg Position (%)	11	39	65	0.014	*
Wetted Width (m)	11	3.16	1.94	< 0.001	***
Active Channel Width (m)	11	3.93	2.73	0.012	*
Channel-full Width (m)	11	6.35	5.62	0.189	–
Channel-full Height (m)	22	1.67	1.28	< 0.001	***
Bank Angle (o)	22	67	49	0.009	**
Vegetative Cover (%)	22	40	28	0.075	–

Table 34. Difference in means t-test results comparing CHAT008 and CHAT010. The significance of the differences is indicated by: "– "not significant; "*" p-value <0.05, "**" p-value <0.01, and "***" p-value <0.001 [mm—millimeters; m—meters].

Measurements	n	CHAT008	CHAT010	P-value	Significance
Pebble Count (mm)	100	40.73	41.82	0.832	–
Thalweg Depth (m)	11	0.19	0.28	0.242	–
Thalweg Position (%)	11	50	67	0.073	–
Wetted Width (m)	11	2.57	3.30	0.047	–
Active Channel Width (m)	11	4.21	4.13	0.844	–
Channel-full Width (m)	11	7.96	8.77	0.348	–
Channel-full Height (m)	22	1.36	1.45	0.417	–
Bank Angle (o)	22	56	50	0.515	–
Vegetative Cover (%)	22	37	30	0.273	–

Table 35. Difference in means t-test results comparing CHAT011 and CHAT014. The significance of the differences is indicated by: "–" not significant; "*" p-value <0.05, "**" p-value <0.01, and "***" p-value <0.001 [mm—millimeters; m—meters].

Measurements	n	CHAT011	CHAT014	P-value	Significance
Pebble Count (mm)	100	34.23	13.90	< 0.001	***
Thalweg Depth (m)	11	0.16	0.25	0.230	–
Thalweg Position (%)	11	47	61	0.156	–
Wetted Width (m)	11	2.96	2.66	0.510	–
Active Channel Width (m)	11	4.04	3.46	0.107	–
Channel-full Width (m)	11	7.30	6.37	0.122	–
Channel-full Height (m)	22	3.13	1.13	0.017	*
Bank Angle (o)	22	59	59	0.979	–
Vegetative Cover (%)	22	41	29	0.092	–

Large Low-Entrenchment (Third-Order) Streams

Reach Descriptions

CHAT001—Haw Creek

On June 12, 2017, stream survey data were collected at Haw Creek (CHAT001). The reach at Haw Creek is along a third-order segment of its stream network. CHAT001 is located approximately 250 meters (820 ft) upstream of a pedestrian bridge and 340 meters (1,115 ft) upstream of its confluence with the Chattahoochee River. A social trail, along river right, runs approximately 10–15 meters (32.8–49.2 ft) from the stream. The reach that was surveyed was 150 meters (492 ft) long with 15 meters (49.2 ft) between transects. CHAT001 is paired with CHAT013 because they are both third-order streams (Table 36) their watersheds have similarly high levels of development (58% and 60%, respectively; Table 37).

CHAT001's channel was not entirely entrenched (large areas of floodplain have developed) though there were relatively high banks throughout the reach (Figure 42). Water surface slope (longitudinal profile) for this section of Haw Creek was 0.0074 m/m (Table 38). The longitudinal profile shows the riffle, run, pool sequences that characterize the reach (Figure 43). The detailed transects were surveyed on T2 (BM1), T6 (BM2), and T8 (BM3). Floodplains were observed on all three detailed transects (Figure 44). Flood chutes were interpreted to be present on detailed transects 1 (T2) and 3 (T8). The gravel island/bar between T4 and T6 was captured by detailed transect 2 (T6). Survey results for CHAT001 can be found in Appendix N.

Table 36. Watershed characteristics for the third-order streams at Chattahoochee River National Recreation Area calculated using the National Elevation Dataset (NED) 10-meter (32.8-ft) digital elevation model [km—kilometers; m—meters; SD—Standard deviation; CV—Coefficient of variation].

Basin Characteristic	CHAT001	CHAT013
Drainage Area (km^2)	8.78	16.88
NPS Managed Area (km^2)	0.03	0.29
NPS Managed Area (%)	0.4%	2%
Total Stream Length (km)	13.97	27.11
Drainage Density	1.59	1.61
Strahler Order	3	3
Bifurcation Ratio	1.57	1.52
Entire Stream Gradient	0.0146	0.0065
Segment Gradient	0.0070	0.0065
Slope—Average	7.13	8.71
Slope—SD	5.07	5.84

Table 36. (continued). Watershed characteristics for the third-order streams at Chattahoochee River National Recreation Area calculated using the National Elevation Dataset (NED) 10-meter (32.8-ft) digital elevation model [km—kilometers; m—meters; SD—Standard deviation; CV—Coefficient of variation].

Slope—CV	0.71	0.67
Basin Length (km)	7.74	10.66
Basin Shape	0.15	0.15
Basin Relief (m)	125.21	108.78
Basin Relief Ratio	0.016	0.010
Elevation—SD (m)	21.09	22.86

Table 37. Land use/land cover characteristics from 2011 for the third-order streams at Chattahoochee River NRA (NLCD 2011 data set; Homer et al. 2015).

NLCD Classes	CHAT001	CHAT013
Developed Open & Low (%)	54	48
Developed Med. & High (%)	4	12
Forested (%)	37	40
Grassland (%)	4	0
Cultivated (%)	0	0

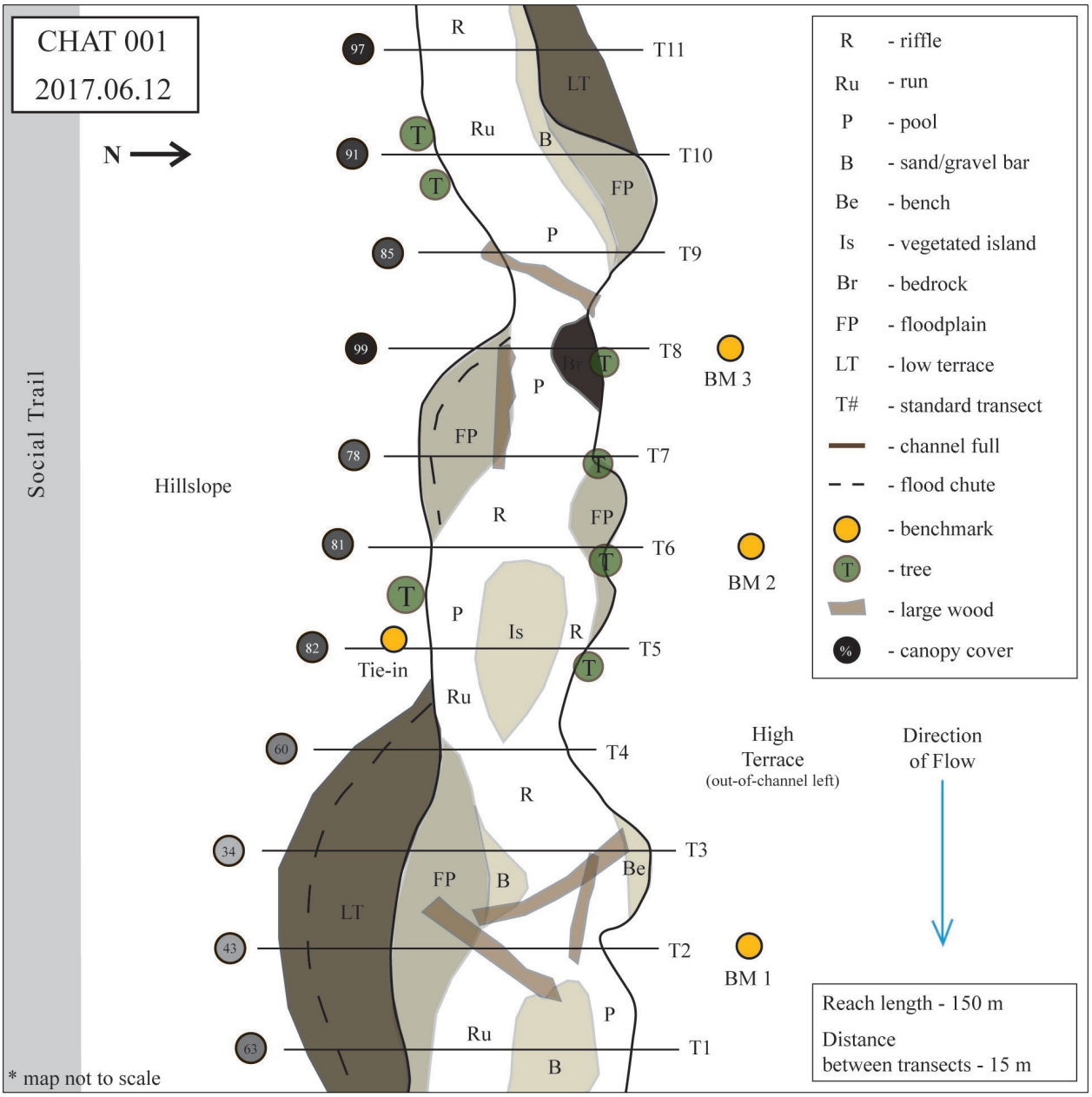


Figure 42. Reach-scale map of CHAT001. Important geomorphic surfaces and in-channel features are labeled to provide a context for the standard and detailed transect information provided in this report. The canopy cover circles are varying shades of grey which indicate the amount of canopy cover at each transect (high and low coverages are labeled).

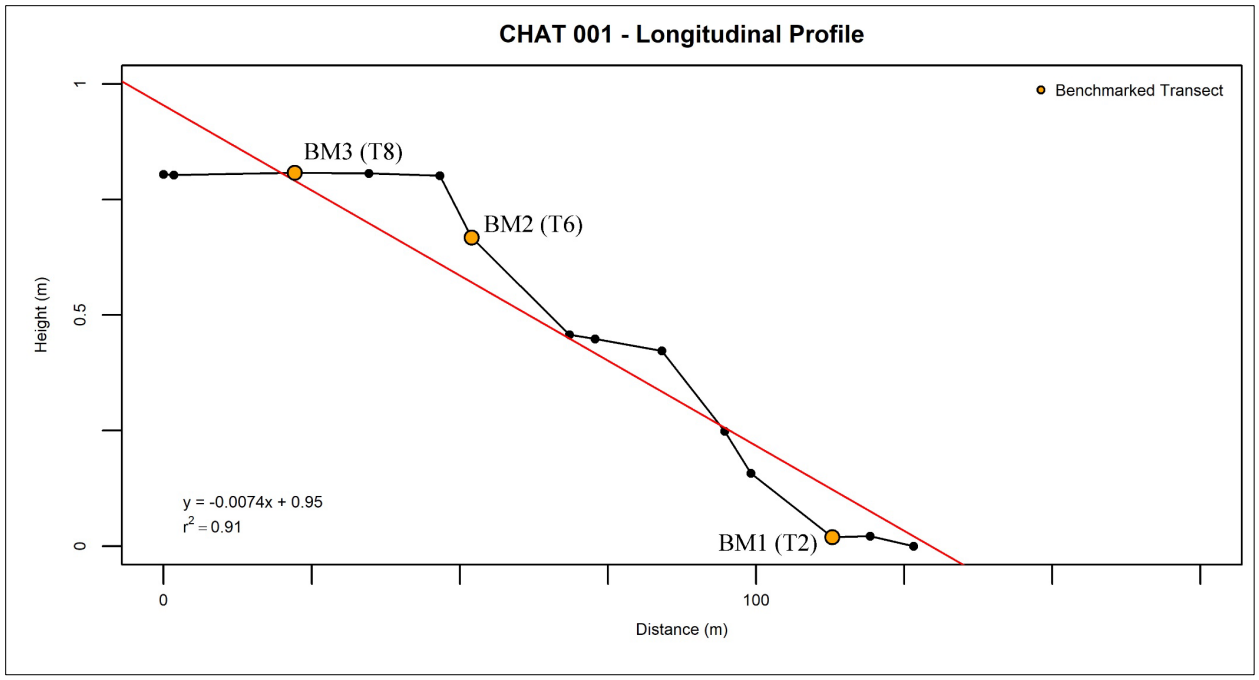


Figure 43. Longitudinal profile for CHAT001. The red line on the graph corresponds to the interpreted slope of the reach. The r^2 value describes the strength of the trend line.

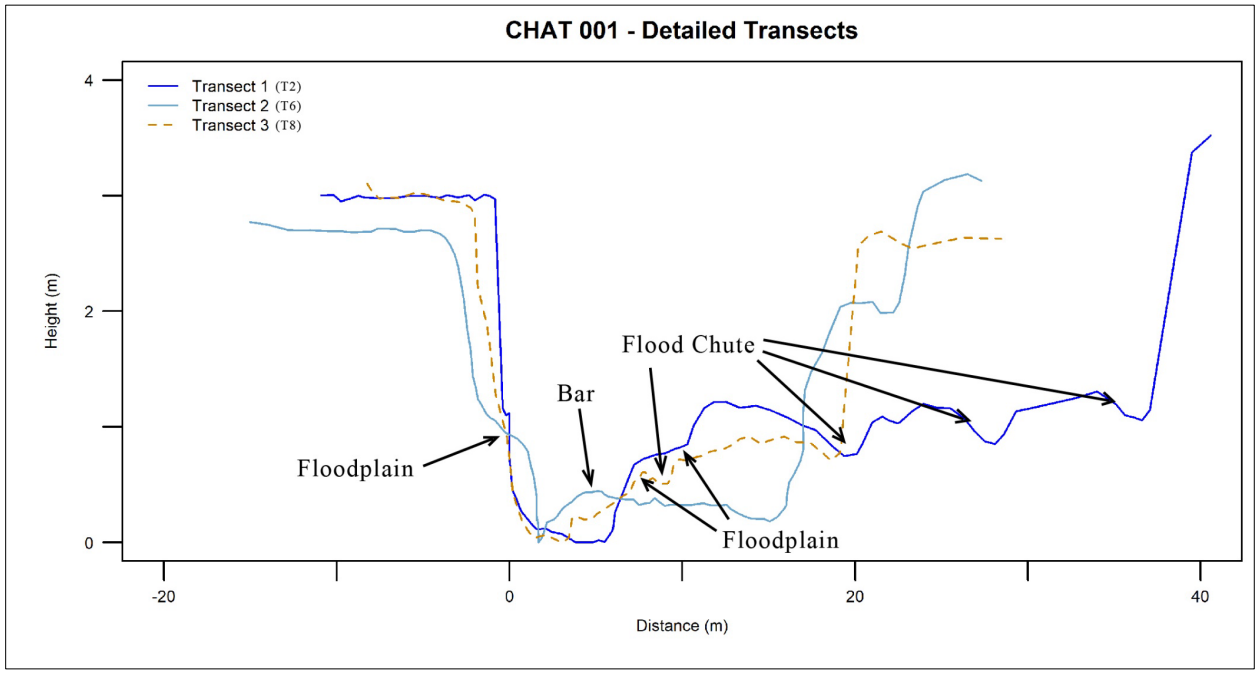


Figure 44. Comparison of the detailed transects at CHAT001. The location of the left channel-full points for each transect are normalized to allow for comparisons between transects.

Table 38. Summary of the results of the detailed transect surveys. Slope and sinuosity measures are based on the water surface and change in slope points taken within the reach. The bankfull and channel-full values are averages of the three detailed transect surveys [m—meters].

Site Number	n[1]	Slope	Sinuosity	n[2]	Bankfull Area (m^2)	Bankfull Width (m)	Bankfull Depth (m)	Channel-full Area (m^2)	Channel-full Width (m)	Channel-full Depth (m)
CHAT001	14	-0.0074	1.07	3	3.97	9.74	0.71	41.40	22.13	2.57
CHAT013	17	-0.0044	1.14	3	5.08	11.39	0.63	26.27	16.72	2.09

[1]Number of measurements for slope and sinuosity

[2]Number of measurements for bankfull area, bankfull width, bankfull depth, channel-full area, channel-full width and channel-full depth

CHAT013—Long Island Creek

On June 13, 2017 stream survey data were collected at CHAT013. CHAT013 is located along Long Island Creek (a third-order stream in the Palisades unit). Long Island Creek can be accessed by taking the hiking trail from the Whitewater Creek parking lot upstream to the site. Long Island Creek was eroding into the hiking trail between T8 and T9 during the survey (Figure 45). The reach that was surveyed was 160 meters (525 ft) long with 16 meters (52.5 ft) between transects. As explained in CHAT001's description, CHAT013 is paired with CHAT001 because their watersheds have high levels of development (58% and 60%, respectively; Table 37) and they are both third-order streams.

The monitored portion of Long Island Creek was highly entrenched and only one area of floodplain has developed within the reach (around T11). Large woody debris had created a series of steps between T9 and T10. Some small bedrock outcrops were influencing the stream around T1, T4, and T8. Water surface slope (longitudinal profile) for this section of Long Island Creek was 0.0044 m/m (Table 38). The longitudinal profile shows the flat pool area between T6 and T8 as well as the higher slope areas at the up- and downstream portions of the reach (Figure 46). The detailed transects were surveyed on T3 (BM1), T6 (BM2), and T11 (BM3). A floodplain was observed on detailed transect 3 (T11) and a bar was captured on detailed transect 1 (T3; Figure 47). Survey results for CHAT013 can be found in Appendix O.

Basin Characteristics

The third-order watersheds drain 8.78 square kilometers (3.39 sq mi; CHAT001) and 16.88 square kilometers (6.52 sq mi; CHAT013; Table 36). Chattahoochee River NRA manages 0.4% of CHAT001's watershed and 2% of CHAT013's watershed. The drainage density of the two watersheds are approximately the same (1.59 km/km^2 and 1.61 km/km^2) and so are their bifurcation ratios (1.57 and 1.52). While the segment gradients of the two streams are nearly the same (0.0070 m/m and 0.0065 m/m), CHAT001's entire stream gradient (0.0146 m/m) is twice that of CHAT013's (0.0065; Table 36). CHAT013 has a slightly higher average watershed slope (8.71°) than CHAT001 (7.13°). The third-order watersheds are long and narrow (basin shape = 0.15). CHAT001 has a slightly higher basin relief ratio (0.016) than CHAT013 (0.010). The land use / land cover (LULC) of the two third-order watersheds is very similar (Table 37). The main difference in LULC is CHAT013 has slightly more commercial and/or industrial land cover (medium and high intensity development, 12% compared to 4%).

Habitat Characteristics

The GCU types and distributions of the two third-order streams are similar but have a few recognizable differences (Table 39). The GCUs at CHAT001 are predominantly pool habitat (53%) with riffles (24%) and runs (17%) between. The GCUs at CHAT013, on the other hand, are predominantly riffle habitats (46%) with pools (39%) and glides (6%) between. Additionally, CHAT013 also has step habitat (created by LWD) between T9 and T10 (Figure 45). While CHAT013 has more "high energy" habitat (higher % riffle than CHAT001), the mean pebble count diameter for CHAT001 (46.10 millimeters [1.81 in]) is much coarser than CHAT013 (24.76 millimeters [0.97 in]; Table 40). This difference in mean pebble diameter is statistically significant (Table 41).

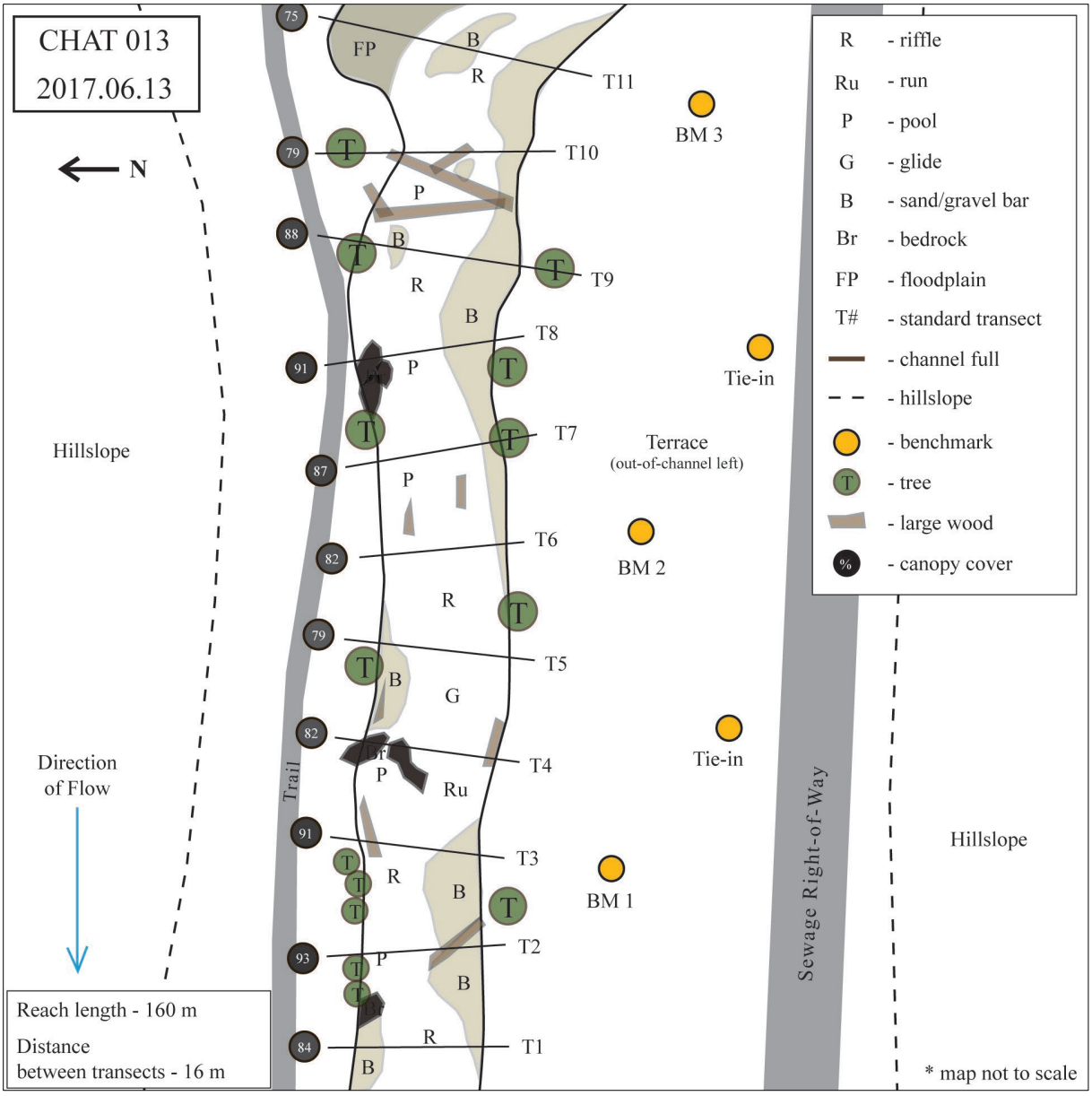


Figure 45. Reach-scale map of CHAT013. Important geomorphic surfaces and in-channel features are labeled to provide a context for the standard and detailed transect information provided in this report. The canopy cover circles are varying shades of grey which indicate the amount of canopy cover at each transect (high and low coverages are labeled).

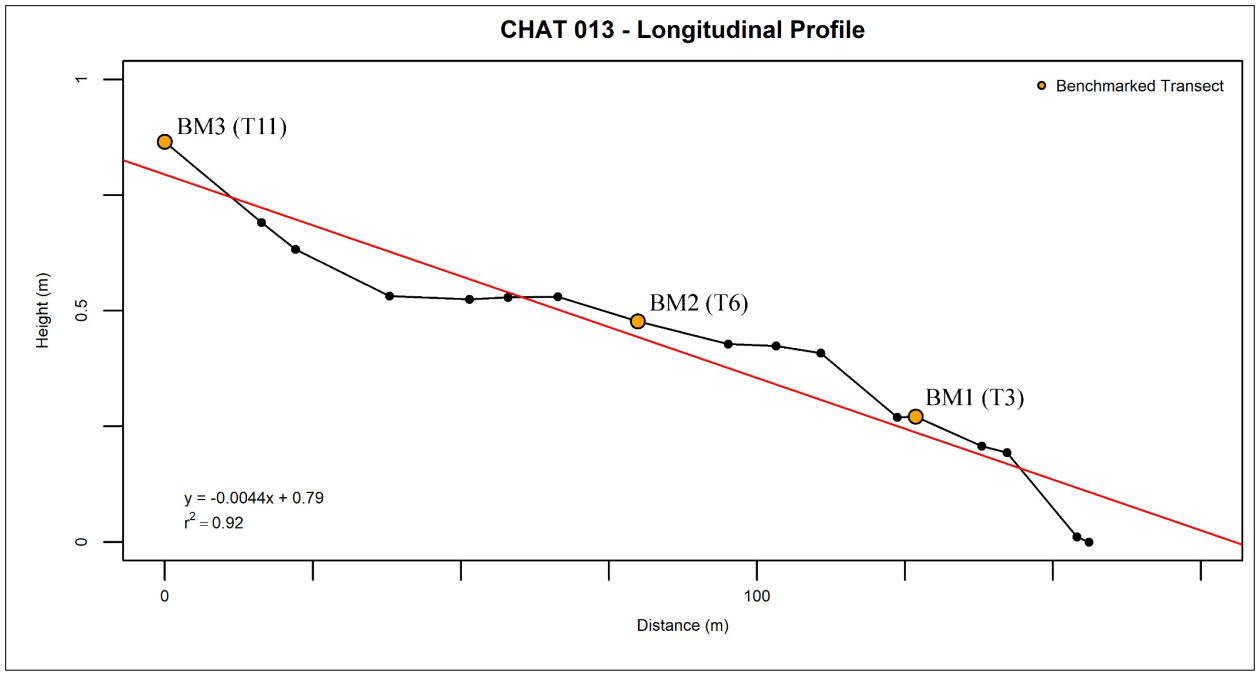


Figure 46. Longitudinal profile for CHAT013. The red line on the graph corresponds to the interpreted slope of the reach. The r^2 value describes the strength of the trend line.

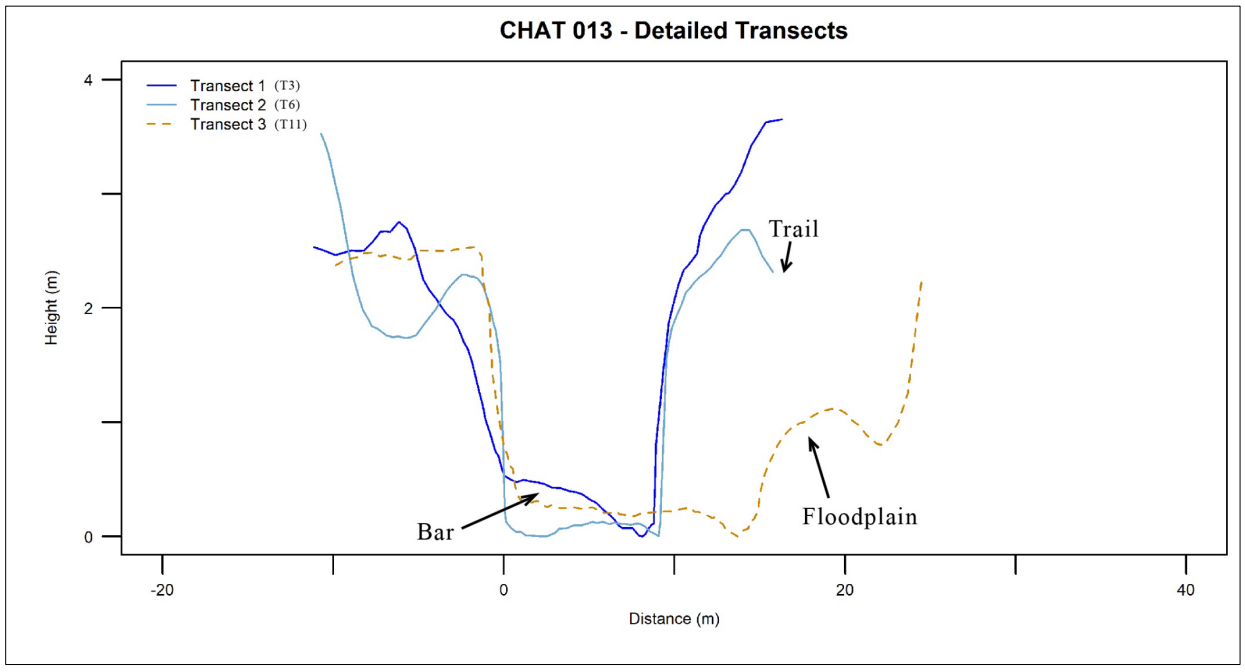


Figure 47. Comparison of the detailed transects at CHAT013. The location of the left channel-full points for each transect are normalized to allow for comparisons between transects.

Table 39. Comparison of GCU observed in the area between transects for the third-order streams at Chattahoochee River NRA. The data describe the percent coverage of each type of GCU [SD—Standard deviation].

GCU Type	Site Number	Frequency	Max (%)	Mean (%)	SD (%)
Riffle	CHAT001	6	100	24	32
	CHAT013	10	85	46	24
Run	CHAT001	5	70	17	23
	CHAT013	3	15	4	6
Glide	CHAT001	1	75	8	24
	CHAT013	1	60	4	27
Pool	CHAT001	8	100	53	39
	CHAT013	10	95	39	27
Step	CHAT001	0	0	0	0
	CHAT013	1	60	6	19

Table 40. Comparison of the particle size distributions of bed sediment (in millimeters [mm]) from the pebble count pebble surveys conducted at the third-order stream sites. The subscripts indicate the percent of the sample that is smaller than the reported diameter.

Statistic (mm)	CHAT001 (n=100)	CHAT013 (n=100)
Min	2.00	0.06
D_5	4.90	2.00
D_{16}	15.00	9.00
D_{50}	44.00	25.00
Mean	46.10	24.76
D_{84}	74.16	41.16
D_{95}	100.35	50.00
Max	187.00	65.00

Table 41. Difference in means t-test results comparing CHAT001 and CHAT013. The significance of the differences is indicated by: "–"not significant; "*" p-value <0.05, "**" p-value <0.01, and "***" p-value <0.001 [m—meters; mm—millimeters].

Measurements	n	CHAT001	CHAT013	P-value	Significance
Pebble Count (mm)	100	46.10	24.76	< 0.001	***
Thalweg Depth (m)	11	0.40	0.27	0.173	–
Thalweg Position (%)	11	56	77	0.096	–
Wetted Width (m)	11	6.59	6.68	0.927	–
Active Channel Width (m)	11	8.01	8.95	0.358	–
Channel-full Width (m)	11	14.14	14.77	0.721	–
Channel-full Height (m)	22	2.09	2.37	0.113	–
Bank Angle (°)	22	48	60	0.154	–
Vegetative Cover (%)	22	53	34	0.019	*

Sixteen pieces of LWD were measured at CHAT001 and 30 pieces of LWD were found at CHAT013 (Table 42). Though CHAT013 had almost twice as many pieces of LWD as CHAT001, the two stream reaches had nearly the same volume per channel area (0.0015 m^3/m^2 [CHAT001] and 0.0019 m^3/m^2 [CHAT013]). The pieces of LWD at CHAT013, except for the large pieces creating the stepped area, were small and the majority of the pieces of LWD at CHAT001 were quite large. Average canopy cover was 74% at CHAT001 and 85% at CHAT013 (Table 43). In addition to having a low average canopy cover, CHAT001 also had high variability in canopy cover (0.29 compared to 0.07 at CHAT013).

Mean thalweg depth was 0.27 meters (0.89 ft) at CHAT013 and 0.40 meters (1.31 ft) at CHAT001 (Table 44). Differences in thalweg depth between CHAT001 and CHAT013 were not statistically significant (Table 41). The coefficient of variation in thalweg position was 0.26 at CHAT013 and 0.58 at CHAT001 (Table 44). The difference in mean thalweg position was not statistically significant (Table 41).

Table 42. Comparison of the summary statistics for the LWD measured at the third-order stream sites [m—meters].

Statistic	Site Number	n	Length (m)	Diameter (m)	Volume (m^3)
Min	CHAT001	16	2.51	0.12	0.04
	CHAT013	30	1.06	0.10	0.01
Mean	CHAT001	16	6.60	0.18	0.20
	CHAT013	30	2.94	0.21	0.15
Max	CHAT001	16	13.17	0.43	0.74
	CHAT013	30	7.17	0.46	0.82
SD	CHAT001	16	3.20	0.08	0.20
	CHAT013	30	1.54	0.10	0.19
Sum	CHAT001	16	–	–	3.23
	CHAT013	30	–	–	4.51
Per Channel Area (m^3/m^2)	CHAT001	–	–	–	0.0015
	CHAT013	–	–	–	0.0019

Table 43. Comparison of the variability in canopy cover at the third-order stream sites [SD—Standard deviation; CV—Coefficient of variation].

Site Number	n	Min (%)	Mean (%)	Max (%)	SD (%)	CV
CHAT001	11	34	74	99	21	0.29
CHAT013	11	75	85	93	6	0.07

Table 44. Comparison of reach-scale averaged thalweg conditions at the third-order stream sites. Depth measurements are in meters (m) and the position is the percent distance from the left bank [SD—Standard deviation; CV—Coefficient of variation].[1]

Thalweg Characteristic	Site Number	n	Min	Mean	Max	SD	CV
Depth (m)	CHAT001	11	0.13	0.4	0.71	0.22	0.56
	CHAT013	11	0.14	0.27	0.77	0.19	0.7
Position[1] (%)	CHAT001	11	5	56	90	33	0.58
	CHAT013	11	30	77	95	20	0.26

[1]position is percent distance from left bank

Channel Morphology

Mean wetted width was 6.59 meters (21.62 ft) at CHAT001 and 6.68 meters (21.92 ft) at CHAT013 (Table 45). The difference in mean wetted width between CHAT001 and CHAT013 was not statistically significant (Table 41). CHAT013 had the narrowest minimum wetted width (3.27 meters [10.73 ft]) while CHAT001 had the widest maximum wetted width (12.26 meters [40.22 ft]). Variability in wetted widths were approximately the same (CV = 0.35 and 0.34). Mean active channel width was 8.01 meters (26.28 ft) at CHAT001 and 8.95 meters (29.36 ft) at CHAT013 (Table 45). The difference in mean active channel width between the two sites was not statistically significant (Table 41). Mean bankfull width was 9.44 meters (30.97 ft) at CHAT001 and 11.09 meters (36.38 ft) at CHAT013. Mean channel-full width was 14.14 meters (46.39 ft) at CHAT001 and 14.77 meters (48.46 ft) at CHAT013 (Table 45). Variability in channel-full widths at both reaches was similar (CV = 0.26 and 0.30). The difference in mean channel-full width between the two sites was not statistically significant (Table 41).

Mean minimum bank height was 1.84 meters (6.04 ft) at CHAT001 and 2.17 meters (7.12 ft) at CHAT013; Table 46). Minimum bank heights were the most variable at CHAT001 (CV = 0.45 compared to 0.28 at CHAT013). Mean bankfull height was 0.74 meters (2.43 ft) at CHAT013 and 0.94 meters (3.08 ft) at CHAT001 (Table 46). CHAT013 had the most variability in bankfull heights (CV = 0.54 compared to 0.28 at CHAT001). Mean channel-full height was 2.09 meters (6.86 ft) at CHAT001 and 2.37 meters (7.78 ft) at CHAT013 (Table 45). The difference in mean channel-full height between the two sites was not statistically significant (Table 41). Variability in channel-full heights was relatively low for CHAT013 (0.12) compared to CHAT001 (0.36; Table 46).

Table 45. Comparison of reach-scale averaged width characteristics of the third-order stream sites [m—meters; SD—Standard deviation; CV—Coefficient of variation].

Widths	Site Number	n	Min (m)	Mean (m)	Max (m)	SD	CV
Wetted	CHAT001	11	4.34	6.59	12.26	2.30	0.35
	CHAT013	11	3.27	6.68	9.30	2.27	0.34
Active Channel	CHAT001	11	5.70	8.01	14.55	2.45	0.31
	CHAT013	11	6.35	8.95	14.00	2.27	0.25
Bankfull	CHAT001	6	7.16	9.44	12.76	2.14	0.23
	CHAT013	3	10.55	11.09	11.75	0.61	0.05
Channel-full	CHAT001	11	8.97	14.14	20.95	3.72	0.26
	CHAT013	11	10.46	14.77	26.65	4.44	0.30

Table 46. Comparison of reach-scale averaged bank characteristics of the third-order stream sites [m—meters; SD—Standard deviation; CV—Coefficient of variation].

Bank Characteristics	Site Number	n	Min	Mean	Max	SD	CV
Bank Height[1,2] (m)	CHAT001	22	0.57	1.84	3.15	0.83	0.45
	CHAT013	22	0.47	2.17	2.99	0.62	0.28
Bankfull Height[1,3] (m)	CHAT001	6	0.57	0.94	1.34	0.26	0.28
	CHAT013	3	0.47	0.74	1.19	0.39	0.54
Channel-full Height[1] (m)	CHAT001	22	0.74	2.09	3.15	0.75	0.36
	CHAT013	22	1.96	2.37	2.99	0.29	0.12
Bank Undercut[3] (m)	CHAT001	5	0.20	0.59	1.62	0.60	1.02
	CHAT013	7	0.09	0.21	0.54	0.15	0.71
Bank Angle (°)	CHAT001	22	13.70	47.55	118.30	27.28	0.57
	CHAT013	22	6.40	59.52	88.40	27.38	0.46
Vegetation Cover (%)	CHAT001	22	5.00	53.41	100.00	31.14	0.58
	CHAT013	22	0.00	34.32	60.00	18.60	0.54
Bank Stability[4]	CHAT001	22	7.00	12.73	17.00	2.25	0.18
	CHAT013	22	9.00	13.70	18.00	2.51	0.18

[1]above thalweg

[2]this height refers to the lowest bank height on either side (bankfull or channel-full)

[3]statistics are based on the transects where feature is present

[4]bank stability score rankings: 4–7 stable; 8–10 at-risk; 11–15 unstable; and 16–22 very unstable

The mean depth of the undercuts measured at CHAT013 was 0.21 meters (0.69 ft) and 0.59 meters (1.94 ft) at CHAT001 (Table 46). Maximum undercut depth was measured at CHAT001 (1.62 meters [5.31 ft]). CHAT001 had the highest variability in undercut depth (CV = 1.02 compared to 0.71 at CHAT013). Mean bank angle was 48° at CHAT001 and 60° at CHAT013 (Table 46). CHAT001's bank angles were slightly more variable than CHAT013 (CV = 0.57 and 0.46, respectively). The difference in mean bank angle between the two sites was not statistically significant (Table 41). Mean bank vegetation cover was 34% at CHAT013 and 53% at CHAT001 (Table 46). The difference in mean vegetative cover between the two sites was statistically significant (Table 41). The mean bank stability scores for the third-order sites (12.7 and 13.7, respectively; Table 46) were classified as "unstable" (see Methods sections for how to interpret bank stability scores). The minimum (best) bank stability score for CHAT001 (7.0) was "stable" while the minimum score for CHAT013 (9.0) was "at-risk." The maximum (worst) bank stability score for both third-order streams (17.0 and 18.0, respectively) was "very unstable."

Channel slope was 0.0044 m/m at CHAT013 and 0.0074 m/m at CHAT001 (Table 38). Though both reaches were relatively straight, reach sinuosity was slightly higher at CHAT013 (1.14) than CHAT001 (1.07). Mean bankfull area was 3.97 square meters (42.73 sq ft) at CHAT001 and 5.08 square meters (54.68 sq ft) at CHAT013 (Table 38). Mean channel-full area was 26.27 square meters (282.77 sq ft) at CHAT013 and 41.40 square meters (445.63 sq ft) at CHAT001. The large mean channel-full area at CHAT001 is due to the large floodplain areas (wide channel-full widths) on detailed transects 1 (T2) and 3 (T8) coupled with the high channel-full banks (Figure 44).

Paired Sites

CHAT001 and CHAT013 were paired because they were the only third-order streams that were suitable for monitoring (McDonald and Starkey 2018). Of the nine variables that were tested, the differences between two (pebble count and bank vegetative cover) were statistically significant (Table 41). Mean pebble diameter at CHAT001 (46.1 millimeters [1.81 in]) was significantly coarser than the mean pebble diameter at CHAT013 (24.8 millimeters [0.98 in]). Mean bank vegetative cover at CHAT001 (23%) was also significantly higher than at CHAT013 (34%).

Implications and Synthesis of Results

This section describes the processes that were observed at each reach and the potential changes that may occur between surveys (next round of surveys to be completed during Spring and Summer 2020). The processes described will be explained within the context of the objectives of the protocol (i.e., basin characteristics that affect channel morphology and habitat, and the status of channel morphology and habitat characteristics). Similar to the results section, the Implications and Synthesis of Results section is divided by Strahler stream order and further subdivided by reach.

Headwater Streams (First Order)

CHAT002—"Undercut Creek"

CHAT002's watershed is steep and forested. Approximately 80% of the watershed is forested while the remainder is covered by residential or suburban development (Table 4). The watershed area draining to "Undercut Creek" (0.32 square kilometers [0.12 sq mi]) is approximately the same size as CHAT012's watershed (0.30 square kilometers [0.12 sq mi]), is larger than CHAT006's (0.20 square kilometers [0.08 sq mi]), and smaller than both CHAT003 and CHAT009's watersheds (both 0.51 square kilometers [0.20 sq mi]; Table 3). CHAT002's watershed has the highest entire stream gradient (0.0616 m/m), the highest segment gradient (0.840 m/m), and the steepest reach gradient (0.0341 m/m; Tables 3 and 5). Additionally, CHAT002's watershed has the third highest basin relief ratio (0.062) and the elevation within the watershed is more variable than all other first-order stream watersheds (highest standard deviation of elevation [17.23 meters or 56.53 ft]). While high slope and relief can contribute to flashier flows, CHAT002's watershed is also the most elongated (lowest basin shape [0.17]). Elongated basins often have less flashy flood regimes than more circular (high basin shape) basins (Gregory and Walling 1973). Gage data are needed to determine the flashiness of the flow at CHAT002.

The reach surveyed on "Undercut Creek" (CHAT002) is not frequented by the public. While there is a trail leading to the stream, off the main trail along the Chattahoochee River, the trail seemed to be used more by local wildlife than visitors to the park. CHAT002's in-stream habitat was relatively high energy (more riffle [59%] than pool [30%]) and the diameter of mean bed sediment (29.9 millimeters [1.2 in]) was the second coarsest out of all first-order streams (Tables 6 and 7). This reach had the highest volume of LWD per channel area (0.105 m^3/m^2) and the presence of trees near the channel throughout the reach indicates additional large woody debris (LWD) may be available to create habitat or protect banks in the future (Table 9 and Figure 6). The distribution of GCU within the reach indicate a high-energy system which could be detrimental to instream biota, though the combination of coarse bed material and high volume of LWD likely has a positive effect on the benthic macroinvertebrate assemblage (Allan and Castillo 2007). Based on the GCU, bed sediment, and LWD within the reach, CHAT002's instream habitat was classified as "good." This classification is a generalized interpretation of in-stream habitat and additional work is needed to determine how flow (e.g., flashiness of flow and baseflow conditions), water quality, and in-stream physical characteristics affect biodiversity and stream health at CHAT002. Habitat at CHAT002 will likely continue to be "good" unless fine bed material is deposited within the reach, LWD decreases due to downstream transport, or habitat (GCU) diversity decreases (Allan and Castillo 2007). One potential

way that habitat diversity may decrease is if the downstream knickpoint migrates upstream into the reach. Additionally, if there is a substantial upstream disturbance, the sediment delivered to the reach may cause a fining of the bed and loss of habitat that would degrade the CHAT002's habitat.

The major defining morphological characteristics of the surveyed reach were the heavy undercutting on the outside of the bend between T5 and T6 and the presence of the flood chutes on river left (Figure 6). The current processes that are affecting CHAT002 are related to LWD and slumping. As the stream erodes and undercuts its banks, more LWD will be introduced to the stream. These pieces of LWD are important for habitat creation and bank protection. Though a stream may look negatively impacted immediately after a significant tree fall, LWD is usually beneficial to stream biota by increasing the complexity of in-stream habitat (Allan and Castillo 2007; Benke et. al. 1984; Smock et. al. 1989; Lemly and Hilderbrand 2000). The benches between T6 and T10 and the 'floodplain' on T3 river left are likely the result of bank slumping. While slumping can cause a large increase in sediment delivery, these slumps can also create important out-of-channel areas for flood waters and can be a sediment sink if vegetation can become established and the slump/bench is stabilized (Royall et al. 2010). The biggest disturbance that will affect CHAT002 is the upstream migration of a knickpoint that is currently approximately 20–30 meters (65.6–98.4 ft) downstream. Upstream migration of the knickpoint will cause the reach to incise as the stream equilibrates to this lower base level (current level of the Chattahoochee River).

CHAT003—"Steep Draw Creek"

CHAT003's watershed is steep and forested. Approximately 86% of the watershed is forested while the rest is covered by residential or suburban and commercial development (Table 4). The watershed draining to "Steep Draw Creek"' is the same size as CHAT009's watershed (0.51 square kilometers [0.20 sq mi]) and is larger than the other three first-order stream watersheds (Table 3). CHAT003's watershed has the third highest entire stream gradient (0.0531 m/m), the second highest segment gradient (0.0385 m/m), and the second steepest reach gradient (0.0313 m/m; Tables 3 and 5). Additionally, CHAT003's watershed has the second highest basin relief ratio (0.066), the second highest average watershed slope (11.02°), the second highest standard deviation of elevation (16.64 meters [54.59 ft]), and the highest basin shape (0.30; Table 3). These characteristics suggest that CHAT003's flow regime is likely flashy, though gage data is needed to confirm this interpretation. Additional urban or suburban development in the watershed will cause the stream to be flashier.

The reach surveyed on "Steep Draw Creek" (CHAT003) is not frequently visited by the public. While there is a trail leading to the stream off the main trail along the Chattahoochee River, the trail seemed to be used more by local wildlife than visitors to the park. CHAT003's in-stream habitat was very high energy (83% riffle and 13% pool) and the mean diameter of bed sediment (39.05 millimeters [1.54 in]) was the coarsest of all first-order streams (Tables 6 and 7). While riffle habitats can indicate a healthy stream, this reach lacked habitat heterogeneity thought to promote biodiversity (Allan and Castillo 2007; Palmer et al. 2010). This reach had the second highest volume of LWD per channel area (0.0067 m^3/m^2, Table 9) due, in large part, to the tree fall that was influencing the stream between T9 and T11 (Figure 9). Though the reach had coarse bed sediment and a high volume of LWD per channel area, due to the low diversity in GCU, CHAT003's instream habitat was

classified as “fair.” This classification is a generalized interpretation of in-stream habitat and additional work is needed to determine how flow (e.g., flashiness of flow and baseflow conditions), water quality, and in-stream physical characteristics affect biodiversity and stream health at CHAT003. If the bed material at CHAT003 becomes finer and if the GCUs within the reach become more homogenous, the habitat classification may degrade to “poor.” Alternatively, stable (non-mobile) LWD may increase habitat diversity and provide more stability to the reach that could upgrade the classification to “good” (Allan and Castillo 2007). Additionally, the knickpoint immediately downstream from the reach may have a significant impact on the reach and cause its habitat to degrade due to bed incision, changes in channel morphology, and loss of habitat diversity.

The major defining characteristic of the stream was its relatively high degree of entrenchment. The reach had a relatively narrow channel-full width because there were only a few areas where floodplains have developed. Though the reach had a low average channel-full width, it did have the highest channel-full area because of the uniformly high banks. The benches on T2, T4, and T11 indicate the stream is beginning to create floodplains through undercutting and slumping (Figure 9). The main disturbance that will affect CHAT003 is the upstream migration of a knickpoint (currently approximately 5–10 meters [16.4–32.8 ft] downstream) that will cause the reach to incise as the stream equilibrates to this lower base level (current level of the Chattahoochee River).

CHAT006—“Three Mind Creek”

CHAT006’s watershed has low slope and relief and is mostly covered by residential, suburban, and commercial development. Approximately 62% of the watershed is covered by residential/suburban and commercial development and 37% is forested (Table 4). The watershed draining to “Three Mind Creek” is the smallest (0.20 square kilometers [0.08 sq mi]) out of all other first-order watersheds (Table 3). CHAT006’s watershed has the second highest entire stream gradient (0.0537 m/m), the lowest segment gradient (0.0186 m/m), and the third steepest reach gradient (0.0236 m/m; Tables 3 and 5). The majority of CHAT006’s reach is very flat. The reach gradient is artificially high because of the large increase in slope between T3 and T4 (Figure 13). CHAT006’s watershed has the second lowest basin relief ratio (0.053), the lowest average watershed slope (8.36°), the lowest standard deviation of elevation (12.00 meters [39.37 feet]), and the second lowest basin shape (0.18; Table 3). Though gage data are needed to determine the flashiness of the flow regimeat CHAT006, the geomorphic characteristics of the stream suggest the stream does not have a flashy flow regime. Alternatively, the high level of development in the watershed may counteract the dampening effects of the geomorphic characteristics.

The reach that was surveyed on “Three Mind Creek” (CHAT006) is not frequently visited by the public. While there is a trail within 40 meters (131.2 ft) of the creek (path on hillslope on river left) there are no defined trails to or near the stream. CHAT006’s in-stream habitat was very low energy (58% pool and 12% run) and the mean diameter of the bed sediment (10.93 millimeters [0.43 in]) was by far the finest out of all first-order streams (Tables 6 and 7). This reach lacked habitat heterogeneity thought to promote biodiversity (Allan and Castillo 2007; Palmer et al. 2010). CHAT006’s reach had the third highest volume of LWD per channel area (0.0033 m^3/m^2; Table 9) but all of it was concentrated in the step between T3 and T4 (Figure 12). Though there was a

relatively high volume of LWD in the reach, based on the GCU (homogenous and low energy) and bed sediment (very fine), CHAT006's instream habitat was classified as "poor." This classification is a generalized interpretation of in-stream habitat and additional work is needed to determine how flow (e.g., flashiness of flow and baseflow conditions), water quality, and in-stream physical characteristics affect biodiversity and stream health at CHAT006. The habitat classification at CHAT006 may be upgraded to "fair" if stable (non-mobile) in-channel (non-bridging) LWD increases the diversity of habitat, and upstream conditions reduce the amount of fine sediment that is delivered to the reach (Allan and Castillo 2007). Currently, most of the LWD resides in a single step and has minimal effect on GCUs and habitat creation. The LWD step is increasing channel stability, by preventing a knickpoint from migrating upstream into the reach. If and when this LWD step fails, habitat within the reach may change significantly.

The major defining characteristics of the stream were the large change in slope between T3 and T4 (Figure 13) and the transition from relatively low banks and extensive floodplain surfaces to high entrenchment below this knickpoint (Figure 14). The knickpoint between T3 and T4 is due to the creek equilibrating to the level of its parent stream, the Suwannee Creek. The LWD step between T3 and T4 is delaying the upstream migration of the knickpoint. The relative lack of LWD in the reach suggests that the knickpoint may quickly migrate upstream once the LWD step breaks or is bypassed. An interesting characteristic of "Three Mind Creek" is the presence of paired floodplain surfaces along the entire length of the reach above the knickpoint. These longitudinally continuous surfaces may be the result of extensive bank slumping. The process of bank slumping and floodplain development may continue to operate downstream as the stream incises and the banks begin to equilibrate to the new bed level.

CHAT009—Fox Creek

CHAT009's watershed has low slope and relief and is mostly forested. Approximately 75% of the watershed is forested and 22% is developed (Table 4). The watershed draining to Fox Creek is the same size as CHAT003's watershed (0.51 square kilometers [0.20 sq mi]) and larger than the other three first-order watersheds (Table 3). CHAT009's watershed has the lowest entire stream gradient (0.0457 m/m), the second lowest segment gradient (0.0204 m/m), and the surveyed reach had the gentlest channel gradient (Tables 3 and 5). CHAT009's watershed has the lowest basin relief ratio (0.043), the second lowest average watershed slope (8.65°), and the third highest basin shape (0.26; Table 3). The geomorphic attributes (low slope and relief) coupled with the LULC characteristics of the watershed (high forest cover) suggest the stream does not have a flashy flow regime. Though, the more circular basin (relatively high basin shape) may cause the flow regime of the watershed to be flashier than the low slope and relief would suggest. As with the other streams, gage data are needed to determine the actual discharge characteristics of the reach.

The reach surveyed on Fox Creek (CHAT009) is not frequently visited by the public. While there is a trail within 40 meters (131.2 ft) of the creek (path on hillslope on river left) there are no defined trails near the stream. The reach had a variety of in-stream habitats though the energy was relatively low (high percent run habitat; Table 6). The average diameter of the bed material (23.68 millimeters [0.93 in]) was moderately coarse (Table 7). While there were fewer larger particles (low D_{95}) in the stream,

there were also fewer very fine particles (high D_{16}). The reach had very little LWD (0.0014 m^3/m^2; the second lowest volume per channel area; Table 9). The low volume of LWD may indicate that habitat for macroinvertebrates is sub-optimal; conversely, the relatively coarse bed sediment coupled with a low number of very fine bed particles may be interpreted as beneficial (Allan and Castillo 2007). Based on the average conditions of GCU, bed sediment, and LWD within the reach, CHAT009's instream habitat was classified as "fair." This classification is a generalized interpretation of in-stream habitat and additional work is needed to determine how flow (e.g., flashiness of flow and baseflow conditions), water quality, and in-stream physical characteristics affect biodiversity and stream health at CHAT009. If the bed material at CHAT009 becomes finer and if the GCUs within the reach become more homogenous, the habitat classification may degrade to "poor." Alternatively, addition of LWD to the reach may increase habitat diversity and provide more bed stability that could upgrade the classification to "good" (Allan and Castillo 2007).

The major defining characteristics of the stream were the large undercut at T6 and the presence of the benches between T1 and T3, along T5, and between T8 and T11. The undercut will eventually fail and the two large trees that are being undercut may topple into the stream. The stream is far enough away from private property that it is unlikely the trees will cause damage to property when they fall. These very large trees will greatly affect the long-term development of the stream if they fall into or across the stream. Undercut heights were approximately at the same level as the tops of the in-reach benches. This similarity of heights was interpreted as evidence that the stream is developing its floodplain through slumping of undercuts and stabilization of the resultant benches. While the reach had low sinuosity (1.12; Table 5), the coefficient of variation of thalweg position was relatively high (0.61; Table 11). The high CV of thalweg position indicates that the stream may be beginning to develop a meandering planform within the entrenched channel (Simon and Darby 1999).

CHAT012—Cabin Creek

CHAT012's watershed is steep and forested. Approximately 75% of the watershed is forested and 23% is developed (Table 4). The watershed draining to Cabin Creek is approximately the same size as CHAT002's watershed (0.30 square kilometers [0.12 sq mi]), is smaller than CHAT003 and CHAT009's watersheds, and larger than CHAT006's watershed (Table 3). CHAT012 has the second lowest entire stream gradient (0.0459 m/m), the third highest segment gradient (0.0378 m/m), and the second lowest reach gradient (0.0234 m/m; Tables 3 and 5). CHAT012's watershed has the highest basin relief ratio (0.073), the highest average watershed slope (11.87°), and the second highest basin shape (0.29; Table 3). Though CHAT012's watershed has high slope and relief, the low network entire stream gradient, average segment gradient, and low reach slope indicate CHAT012 is located in a relatively low energy portion of the network. Stormflow is likely to have less erosive potential in this portion of the stream than in steeper portions of the stream network; though gage data are needed to confirm this interpretation. Habitat within the reach may degrade to a "poor" rating if fine or very fine sediment is added to the reach (potentially from a disturbance upstream or from the eroding adjacent trail). Conversely, if introduced LWD increases the diversity of habitat and upstream conditions reduce the amount of fine sediment deposited in the reach, it may result in an upgrade of habitat to a "good" classification (Allan and Castillo 2007).

The reach surveyed on Cabin Creek (CHAT012) was actively eroding into a hiking trail on river left (between T4 and T7; Figure 17). The bank was undercut on T6, further destabilizing the trail in this portion of the reach. The reach had a variety of GCUs (50% riffle and 30% pool; Table 6) and the average diameter of bed sediment was relatively low (22.21 millimeters [0.87 in]; Table 7). The relatively fine bed sediment was potentially related to the relatively low energy network setting. The reach had the lowest volume of LWD per channel area (0.0008 m^3/m^2; Table 9) and these pieces of LWD were concentrated in the step at T3 (Figure 18). Low levels of LWD and fine bed sediment may indicate sub-optimal habitat conditions for benthic macroinvertebrates (Allan and Castillo 2007). Though the reach had a variety of GCUs, due to the relatively fine bed sediment and low volume of LWD within the reach, CHAT012's instream habitat was classified as "fair." This classification is a generalized interpretation of in-stream habitat and additional work is needed to determine how flow (e.g., flashiness of flow and baseflow conditions), water quality, and in-stream physical characteristics affect biodiversity and stream health at CHAT012.

The surveyed channel on Cabin Creek was narrow with low banks. There was a large difference (0.16 meters [0.52 ft]) between the upstream bankfull heights (between T9 and T11) and the mid-reach bankfull heights (between T4 and T7; Appendix L). This difference in bankfull heights was interpreted as the result of different processes creating these surfaces. Based on its locations within the reach, the mid-reach floodplain is interpreted as a constructional feature (point bar building and floodplain creation through meander migration). Though the upstream floodplain is located on the inside of a meander bend, due to its morphology (low height), it is interpreted as a stabilized slump or bench. Further sedimentological work is needed to determine the actual processes that created these floodplains. In-reach slope was gentle, except at the step on T3. If this step is destroyed or bypassed, the stream bed upstream of T3 may incise. This potential headward migration of a knickpoint could add additional stress (energy) to the area of the stream (between T4 and T7) that is eroding into the hiking trail.

Medium-Sized (Second Order) Streams

CHAT004—"Crayfish Creek"

CHAT004's watershed has medium to high slope and relief and has a high amount of development. Approximately 56% of the watershed is developed and 39% is forested (Table 19). The watershed draining to "Crayfish Creek"' (1.39 square kilometers [0.54 sq mi]) is smaller than four of the seven other second-order watersheds (Table 21). Compared to the other second-order watersheds, CHAT004's watershed has an intermediate entire stream gradient (0.0232 m/m), the second lowest segment gradient (0.0135 m/m), and an average reach gradient (0.0114 m/m; Tables 21 and 20). CHAT004's watershed has the lowest drainage density (1.18 km/km^2), the second highest basin relief ratio (0.032), the second highest average watershed slope (8.30°), and a relatively low standard deviation of elevation (14.41 meters [47.23 ft]; Table 21). Though CHAT004's watershed has the lowest drainage density, the other geomorphic characteristics (i.e., relatively high slope and relief), coupled with the high percent of development, suggest the stream likely has a flashy flow regime. Additionally, the GIS-derived drainage density may be artificially low due to parking lots and other types of development paving over or obscuring the natural flow network. Gage data are needed to determine the actual discharge characteristics of the reach.

The reach that was surveyed on "Crayfish Creek" (CHAT004) is not frequented by the public. While there is a trail within 10 meters (32.8 ft) of the creek (path on river left) this portion of Ors Ferry is not readily accessible (have to use a right-of-way on private land to access). The reach had a good mixture of GCUs with slightly more riffle (39%) than pool (35%) habitat (Table 22). The mean diameter of bed material (50.82 millimeters [2.00 in]) was the coarsest out of all second-order streams (Table 23). The coarse bed material is another indication that the stream potentially has a flashy flow regime. The reach had the largest piece of LWD measured at all second-order streams (1.61 m^3; Table 25). "Crayfish Creek" also had the highest volume of LWD per channel area (0.067 m^3/m^2). Though the reach had the highest volume of LWD, the majority of the pieces of LWD were bridging the stream and not actively providing habitat within the stream. High volumes of LWD, coarse bed material, and a mix of GCUs is indicative of relatively good habitat for benthic macroinvertebrates, as long as these features are stable and not frequently altered or shifted by flashy flows (Allan and Castillo 2007). Based on the GCU, bed sediment, and LWD within the reach, CHAT004's instream habitat was classified as "good." This classification is a generalized interpretation of in-stream habitat and additional work is needed to determine how flow (e.g., flashiness of flow and baseflow conditions), water quality, and in-stream physical characteristics affect biodiversity and stream health at CHAT004. Habitat at CHAT004 will likely continue to be 'good' unless fine bed material is deposited within the reach (potentially from upstream disturbance or undercut failure), LWD decreases due to downstream transport, and habitat (GCU) diversity decreases (Allan and Castillo 2007).

The major defining characteristics of "Crayfish Creek"' were the entrenched nature of the stream and the alternating (meandering) bars in the area between T3 and T10 (Figure 9). CHAT004 had the highest minimum bank heights (1.67 meters [5.48 ft]; Table 30), highest bank angles (67.29°; Table 32), and the largest channel-full area (7.37 square meters [79.33 sq ft]; Table 20). Additionally, the reach had the highest occurrence of undercutting (n = 13; Table 32). Widespread bank slumping and potential tree failure is likely due to the high steep banks and the high occurrence of undercutting. The reach at CHAT004 had the lowest sinuosity (1.02) out of all second-order streams (Table 20). While the reach had the lowest sinuosity, the reach had a high CV of thalweg position (0.60; Table 27); indicating that the thalweg has begun to meander within the entrenched channel. This incipient meandering has contributed to the construction of alternating (side) bars in the middle portion of the reach (between T5 and T9; Figure 9). Similar to many of the other streams with high CV of thalweg position, CHAT004 is beginning to reestablish a meandering planform within the entrenched channel (Simon and Darby 1999). Due to the highly entrenched nature of the stream, the cohesive banks, and the relatively high frequency of undercutting, lateral migration is not significantly affecting the reach. As the stream begins to reestablish a meandering planform, lateral migration will become an important contributor to the amount of sediment produced by the reach.

CHAT005—"Egg Creek"

CHAT005's watershed is steep and forested. Approximately 83% of the watershed is forested and 12% is developed (Table 19). The watershed draining to "Egg Creek" (0.77 square kilometers [0.30 sq mi]) is the smallest of all second-order streams (Table 21). Compared to the other second- order watersheds, CHAT005's watershed has the highest entire stream gradient (0.0435 m/m), an

intermediate segment gradient (0.0158 m/m), and the second steepest reach gradient (0.0124 m/m; Tables 21 and 20). CHAT005's watershed has the highest average slope (8.38°), highest basin relief ratio (0.051), highest basin shape (0.39), and the lowest CV of slope (0.65; Table 21). The high watershed slope and relief coupled with the relatively round watershed (high basin shape) suggests the stream has a flashy flow regime. Conversely, potentially high infiltration rates (high percent forest cover) and lower landscape to stream network connectivity (low drainage density) likely reduces the flashiness of the stream. Gage data are needed to determine the flow characteristics of the reach.

The reach that was surveyed on "Egg Creek" (CHAT005) is located between two trails (on either side of the stream; Figure 10) and there is evidence of visitor use (e.g., dog and foot prints on in-channel [bar] surfaces). The reach had a variety of GCUs with alternating riffle and pool sequences; 44% and 41%, respectively (Table 22). The mean diameter of the bed material (37.83 millimeters [1.49 in]) was moderately coarse compared to the other second-order streams (Table 23). Though, the low D_{16} of bed material indicates that there was a high proportion of fine sediment in the pebble count. The reach had many small pieces of LWD (n = 11; Table 25). The LWD was mostly concentrated in the step above T2 (Figure 10). The pool behind the step above T2 is full of fine sediment. The high quantity of fine particles in the reach may be due to 'backwater' effects of this step on the upstream portions of the stream. The diversity of GCU and presence of LWD are positive benthic macroinvertebrate habitat attributes, yet the high amount of fine sediment may be detrimental to some organisms (Allan and Castillo 2007). Based on the GCU, bed sediment, and LWD within the reach, CHAT005's instream habitat was classified as "fair." This classification is a generalized interpretation of in-stream habitat and additional work is needed to determine how flow (e.g., flashiness of flow and baseflow conditions), water quality, and in-stream physical characteristics affect biodiversity and stream health at CHAT005. If the bed material at CHAT005 becomes finer and if the GCUs within the reach become more homogenous, the habitat classification may degrade to "poor." Alternatively, addition of LWD to the reach may further increase habitat diversity and provide more stability to the reach that could upgrade the classification to 'good' (Allan and Castillo 2007).

The major defining characteristics of the stream were the large knickpoint upstream of T2 and the high occurrence of benches or bars and undercut banks. The LWD step or dam above T2 corresponds with the large increase in slope identified in the longitudinal profile (Figure 25). The LWD step was partially damming the stream and causing bed sedimentation and aggradation immediately upstream. When the dam breaks or is bypassed, this knickpoint will likely migrate upstream. Consequently, the bed will incise and downstream sediment delivery will increase. Similar to many of the other surveyed streams at Chattahoochee River NRA, the high occurrence of benches and bars and undercuts are likely related. More in-channel features will be created as the currently undercut banks fail, slump into the channel, and become these lower surfaces. Though sediment delivery may initially increase when the banks fail, if the slump surfaces can become stabilized by vegetation, they may become incipient floodplains and act as sediment sinks. In addition to being sediment sinks, these lower surfaces can also be refugia for native vegetation that requires more interaction with groundwater.

CHAT007—"Red Tail Creek"

CHAT007's watershed has low slope and relief and is covered by a mixture of forest, development, and grassland. Approximately 42% of the watershed is forested, 31% is developed, and 26% is grassland (Table 19). CHAT007's watershed has by far the most grassland coverage than all other monitored wadeable streams at Chattahoochee River NRA. The watershed draining to "Red Tail Creek" (2.35 square kilometers [0.9 sq mi]) is larger than all other second-order watersheds except for CHAT014 (2.67 square kilometers [1.03 sq mi]; Table 21). Compared to the other second- order watersheds, CHAT007's watershed has the lowest entire stream gradient (0.0160 m/m), the lowest segment gradient (0.0059 m/m), and the second lowest reach gradient (0.0049 m/m; Tables 21 and 20). CHAT007's watershed has the second lowest basin shape (0.18), the highest drainage density (2.06 km/km^2), the lowest average watershed slope (3.82°), the lowest basin relief ratio (0.021), the highest CV of watershed slope (0.89), and the second highest standard deviation of elevation (16.28 meters [53.41 ft]; Table 21). While the majority of the watershed is relatively flat, the high drainage density, CV of slope, and standard deviation of elevation indicate that the watershed is highly dissected and there is a high potential for a large portion of the watershed to be connected to flow paths. Additionally, the high percent of the watershed that is covered by pasture (26%) increases the potential for a flashier flow regime than would be expected based on the slope, relief, and drainage shape (Price et al. 2011). This increased potential for flashier flows is due to the potentially reduced infiltration rates of pastures compared to forests; though gage data are needed to determine the actual flow characteristics of the CHAT007.

The reach surveyed on "Red Tail Creek" (CHAT007) is not frequently visited by the public. Though there is a trail within 30 meters (98.4 ft) of the creek (running through the field on the high terrace on river right), the stream is difficult to access because of the high and steep banks surrounding the inset stream. The reach was low energy and the GCUs that were observed were mostly runs (45%) and pools (32%, with 24% riffle; Table 22). The mean diameter of bed material (8.44 millimeters [0.33 in]) was by far the finest out of all other streams monitored at Chattahoochee River NRA (including first- and third-order streams; Table 23). There was a lot of LWD within the reach (n = 11; Table 25). CHAT007 had the second highest volume of LWD per channel area (0.0063 m^3/m^2) out of all second-order streams. CHAT007 also had the lowest average canopy cover (88%) of all second-order streams (Table 26). The abundance of LWD is a positive benthic macroinvertebrate habitat attribute, yet the high amount of fine bed particles may be negatively affecting benthic organisms (Allan and Castillo 2007). Based on the GCU, bed sediment, and LWD within the reach, CHAT007's instream habitat was classified as "poor." This classification is a generalized interpretation of in-stream habitat and additional work is needed to determine how flow (e.g., flashiness of flow and baseflow conditions), water quality, and in-stream physical characteristics affect biodiversity and stream health at CHAT007. The habitat classification at CHAT007 may be upgraded to "fair" if stable (non-mobile) in-channel (non-bridging) LWD increases the diversity of habitat, and upstream conditions reduce the amount of fine sediment that is delivered to the reach (Allan and Castillo 2007).

The close proximity to the Chattahoochee River has a large influence on the surveyed reach. The major defining characteristics of the stream were the highly entrenched nature of the stream, the presence of multiple terrace levels, and the high occurrence of slumps and slumping. The high

occurrence of slumps and slumping is due to the high steep walls that surround the reach and the frequently fluctuating water table that is caused by the frequent (daily) releases from Buford Dam. The high coefficient of variation of the thalweg position (0.53; Table 27) and the moderately high sinuosity (1.12; Table 20) indicate that the stream is beginning to reestablish a meandering planform inset within the high walls surrounding the stream (Simon and Darby 1999). Immediately upstream of the reach is a knickpoint that is migrating into an extremely entrenched portion of the stream. Sediment delivery to the reach is likely to increase as this knickpoint migrates upstream and the upstream banks begin to fail.

CHAT008—Mulberry Creek

CHAT008's watershed has average slope and relief and is mostly covered by residential and suburban development. Approximately 63% of the watershed is developed and 33% is forested (Table 19). The watershed draining to Mulberry Creek (1.65 square kilometers [0.64 sq mi]) is smaller than CHAT007, 010, and 014's watersheds and larger the other three second-order stream watersheds (Table 21). Mulberry Creek's watershed has the third highest drainage density (1.64 km/km^2). Compared to the other second-order watersheds, CHAT008's watershed has the third highest entire stream gradient (0.0264 m/m), the fourth highest segment gradient (0.0155 m/m), and the steepest reach gradient (0.0142 m/m; Tables 21 and 20). CHAT008's watershed has the third lowest basin relief ratio (0.025), the third lowest average watershed slope (6.78°), and the third lowest basin shape (0.20; Table 21). The slope and relief of the watershed are average to below average which suggests that the stream does not have a flashy flow regime. Alternatively, the high amount of development in the watershed and the high drainage density may contribute to a flashier flow regime than expected based on the other watershed characteristics. Gage data are needed to determine the actual flow characteristics of CHAT008.

The reach surveyed on Mulberry Creek (CHAT008) is not frequently visited by the public. While there is a trail within 40 meters (131.2 ft) of the creek (path on high terrace on river right) there are no defined trails near the stream. The reach had a variety of GCUs, 41% riffle, 11% run, and 49% pool (Table 22). The mean diameter of bed material (40.73 millimeters [1.60 in]) was third coarsest compared to the other second-order stream (Table 23). The sampled riffle also had less fine sediment than the other reaches (coarsest D_{16}). The high reach gradient likely contributes to this lack of fine sediment within the reach. The reach had less LWD (n = 6) than all but two of the other second-order streams (Table 25). The pieces of LWD that were measured in the reach were large and though few pieces were measured, the reach had the third highest volume of LWD per channel area (0.0027 m^3/m^2). Based on LWD, bed material, and diversity of GCU, habitat for benthic macroinvertebrate was classified as "good" in this reach (Allan and Castillo 2007). This classification is a generalized interpretation of in-stream habitat and additional work is needed to determine how flow (e.g., flashiness of flow and baseflow conditions), water quality, and in-stream physical characteristics affect biodiversity and stream health at CHAT008. Habitat at CHAT008 will continue to be "good" unless fine bed material is deposited within the reach, LWD decreases due to downstream transport, and habitat (GCU) diversity decreases (Allan and Castillo 2007).

The major defining characteristic of the stream was the presence of multiple out-of-channel surfaces (i.e., floodplains, low terraces, and high terraces). The reach on Mulberry Creek had the widest active channel width (4.21 meters [13.81 ft]) and the second widest bankfull width (4.95 meters [16.24 ft]; Table 28). Bankfull heights were almost twice as variable (CV = 0.43) as the other second-order streams (Table 30). This high variability in bankfull height may indicate higher (terrace) surfaces were misinterpreted as floodplain surfaces. The presence of multiple out-of-channel surfaces is interpreted multiple levels of stabilized bank slumps. While the reach has the third lowest sinuosity (1.10; Table 20), the average thalweg position CV (0.47; Table 27) and the presence of the alternating bars/floodplains indicates that the stream is returning to a meandering planform inset within the high terrace surfaces (Simon and Darby 1999).

CHAT010—"Beaver Creek"

Compared to the other second-order watersheds, CHAT010's watershed has average geomorphic characteristics (i.e., slope and relief) and is mostly covered by residential and suburban development. Approximately 71% of the watershed is developed (69% Developed-Open and Low) and 27% is forested (Table 19). The watershed draining to "Beaver Creek" (2.01 square kilometers [0.78 sq mi]) is smaller than CHAT007's and CHAT014's watersheds and is larger than the other four second-order watersheds (Table 21). CHAT010's watershed has the third lowest entire stream gradient (0.0217 m/m), the highest segment gradient (0.0279 m/m), and the fourth lowest reach gradient (0.0106 m/m; Table 21 and 20). CHAT010's watershed has the third lowest basin relief ratio (0.025), the second lowest watershed slope (5.39°), the third highest basin shape (0.25), the third lowest drainage density (1.36 km/km^2), and the lowest standard deviation of elevation (12.28 meters [40.29 ft]; Table 21). Though the watershed has a high basin shape and a lot of development, the flashiness of the stream is likely attenuated by the low drainage density and watershed slope. Alternatively, the high segment gradient likely increases the likelihood of flashy flows in this portion of the stream network. Gage data are needed to determine the actual flow characteristics of this reach.

The reach that was surveyed on "Beaver Creek" (CHAT010) is not frequently visited by the public. While there is a trail within 50 meters (164 ft) of the creek (bike path on hillslope on river left) there are no defined trails near the stream. Additionally, this reach is in the area that is currently closed off to the public to allow for revegetation to occur in the area formerly affected by the beaver dam (that was just upstream of the confluence with Terrell Mill Creek). The habitat within the reach consisted of large deep pools (50%), longitudinally extensive and steep riffles (30%), and a few lower energy runs (20%; Table 22). The mean diameter of bed material (41.82 millimeters [1.65 in]) was the second coarsest of the second-order streams (Table 23). The coarse bed material corroborates the interpretation that the high segment gradient likely increases the flashiness of discharge this section of the stream network. The reach had the most pieces of LWD (n = 12) and an average volume of LWD per channel area (0.0023 m^3/m^2; Table 25). Almost all LWD found in the reach were concentrated in a jam between T4 and T6 (Figure 33). The high amount of LWD, the coarse bed material, and the mixture of GCUs may indicate relatively "good" habitat for benthic macroinvertebrates (Allan and Castillo 2007). This classification is a generalized interpretation of in-stream habitat and additional work is needed to determine how flow (e.g., flashiness of flow and baseflow conditions), water quality, and in-stream physical characteristics affect biodiversity and

stream health at CHAT010. Habitat at CHAT010 will likely continue to be "good" unless fine bed material is deposited within the reach (potentially from upstream disturbance), LWD decreases due to downstream transport, and habitat (GCU) diversity decreases (Allan and Castillo 2007). However, given CHAT010 has a relatively steep gradient, it is unlikely that fine sediment will accumulate within the reach (unless there is a substantial upstream disturbance).

The major defining characteristic of the reach was the high capacity channel that has developed inset within the higher (historical) terrace. The reach had the largest average bankfull area (2.04 square meters [21.96 sq ft]) and the second largest average channel-full area (6.35 square meters [68.35 sq ft]) of all second-order streams (Table 20). The reach also had the deepest mean thalweg (0.28 meters [0.92 ft]; Table 27). Mean bank angle (49.92°) was the second lowest and the most variable (CV = 0.63) due to the high occurrence of low slope bars (point bars) grading up to the floodplain and bankfull areas contrasting with the high steep banks where floodplains have not developed (Table 32). Though there were large increases in channel slope within the reach (Figure 34), it is not likely that the reach will incise because the high slope riffle areas were armored by gravels and cobbles.

CHAT011—Gunby Creek

Compared to the other second-order watersheds, CHAT011's watershed has average slope and relief and is the least forested second-order watershed. Approximately 81% of the watershed is developed and 19% is forested (Table 19). The watershed draining to Gunby Creek (1.01 square kilometers [0.39 sq mi]) is larger than CHAT005's watershed but smaller than all other second-order watersheds (Table 21). CHAT011's watershed has the second highest entire stream gradient (0.0328 m/m), the second highest segment gradient (0.0179 m/m), and the third lowest reach gradient (0.0087 m/m; Tables 21 and 20). CHAT011's watershed has the third highest basin relief ratio (0.029), an intermediate watershed slope (7.47°), the lowest basin shape (0.15), and the highest standard deviation of elevation (17.8 meters [58.40ft]; Table 21). While the shape of the watershed will attenuate flood flows, the high entire stream gradient and relatively high watershed slope and relief coupled with the high developed cover suggest the stream has a flashy flow regime; though gage data are needed to confirm this interpretation.

The reach surveyed on Gunby Creek (CHAT010) is not frequently visited by the public. Though there is a trail within 10 meters (32.8 ft) of the creek (along sewage right-of-way on river left) there were no defined trails to the stream. The GCUs within the reach were composed of riffle (42%), pool (30%), and run (28%) habitats (Table 22). Gunby Creek had the lowest occurrence of pool habitat out of all second-order streams. The mean diameter of bed material (34.23 millimeters [1.35 in]) was slightly coarser than average (approximately 32 millimeters [1.26 in]; Table 23). Also, the reach had the coarsest D_5 (3.95 millimeters [0.16 in]) and the largest particle (330.00 millimeters [12.99 in]) measured at all second-order streams. The characteristics of the bed sediment along this reach corroborate the interpretation that this reach is influenced by a flashy discharge regime. CHAT011 had no LWD within the reach (Table 25). Though the reach had relatively coarse bed sediment and a mixture of GCUs, the lack of LWD is indicative of sub-optimal habitat conditions for benthic macroinvertebrates (Allan and Castillo 2007). Based on the GCU, bed sediment, and LWD within the reach, CHAT011's instream habitat was classified as "fair to good." This classification is a

generalized interpretation of in-stream habitat and additional work is needed to determine how flow (e.g., flashiness of flow and baseflow conditions), water quality, and in-stream physical characteristics affect biodiversity and stream health at CHAT011. The habitat classification at CHAT011 may be upgraded to "good" if stable (non-mobile) in-channel (non-bridging) LWD enhances habitat diversity. Alternatively, if the bed material becomes finer (due to upstream input or within reach bank failures) and habitat (GCU) diversity decreases the reach could be downgraded to "fair" or "poor" (Allan and Castillo 2007).

The major defining characteristics of the stream were the longitudinally extensive floodplain along river right (T1–T5) and the hillslope influencing river right upstream of T6. While the reach had the second lowest sinuosity (1.06; Table 20) and an average CV of thalweg position (0.48; Table 27), the longitudinally extensive floodplain along river right indicates that the stream has been consistently migrating away from the hillslope in this portion of the reach. The influence of the hillslope upstream of T6 artificially inflates the average bank heights for the reach. The channel itself was not very large compared to the other second-order streams (intermediate channel-full area [4.96 square meters or 53.39 sq ft]; Table 20). Bankfull area (0.85 square meters [9.15 sq ft]) was the lowest out of all second-order streams (Table 20). The biggest disturbance that may influence the stream is a meander neck cutoff that is developing approximately 20 meters (65.6 ft) downstream. When this downstream portion of the creek cuts through its bank (meander neck), channel slope immediately downstream from the reach will increase. This increase in slope could have a significant influence on the reach if there is enough energy to cause bed incision and creation of a knickpoint.

CHAT014—Whitewater Creek

CHAT014's watershed has intermediate slope and low relief and is covered by a mixture of forest and residential and suburban development. Approximately 52% of the watershed is forested and 47% is developed (Table 19). The watershed draining to Whitewater Creek (2.67 square kilometers [1.03 sq mi]) is larger than all other second-order watersheds (Table 21). CHAT014's watershed has the second lowest entire stream gradient (0.0167 m/m), the third lowest segment gradient (0.0145 m/m), and the lowest reach gradient (0.0026 m/m; Tables 21 and 20). Compared to the other second-order streams, CHAT014's watershed has the third highest average watershed slope (8.05°), the second lowest coefficient of variation of slope (0.61), the third lowest basin shape (0.24), the second lowest basin relief ratio (0.024), and an intermediate standard deviation of elevation (14.45 meters [47.41 ft]; Table 21). Based on the relatively low relief and low network, segment, and channel slope, the stream likely does not have a flashy flow regime; though gage data are needed to confirm this interpretation.

The reach surveyed on Whitewater Creek (CHAT014) is not frequently visited by the public. While there is a road within 15 meters (49.2 ft) of the creek (on river left) the reach is upstream of the parking lot, is separated from the road by thick undergrowth, and there are no defined trails near the stream. The reach was very low energy (76% pool) and only two riffles (8%) were observed within the reach (Table 22). Bed material was fine and mean pebble size (13.87 millimeters [0.55 in]) was only coarser than CHAT007 (Table 23). The fine bed material corroborates the interpretation that this reach does not have a flashy flow regime. The reach had very few pieces of LWD (n = 2) and the

lowest volume of LWD per channel area (0.0011 m^3/m^2; Table 25). The low volume of LWD, the low heterogeneity of GCU, and fine bed sediment are all indicative of sub-optimal habitat conditions for benthic macroinvertebrates (Allan and Castillo 2007). Based on these physical characteristics, CHAT014's instream habitat was classified as "poor." This classification is a generalized interpretation of in-stream habitat and additional work is needed to determine how flow (e.g., flashiness of flow and baseflow conditions), water quality, and in-stream physical characteristics affect biodiversity and stream health at CHAT011. Habitat at CHAT014 will continue to be "poor" until in-channel LWD increases the diversity of habitat and upstream conditions reduce the amount of fine sediment that is delivered to the reach (Allan and Castillo 2007). Additionally, the drastic reduction in downstream channel gradient (due to the downstream culvert) suggests that significant changes to in-reach sediment storage is unlikely and substantial changes to in-reach morphology will be required to change the habitat within the reach.

The major defining characteristics of the stream were its high sinuosity, small channel, and flood chute (between T4 and T10; Figure 39). Whitewater Creek had the highest reach sinuosity (1.50; Table 20) and the second lowest CV of thalweg position (0.39; Table 27). Unlike a lot of the other streams that were surveyed at Chattahoochee River NRR, CHAT014 has high sinuosity and low variability in thalweg position. More fieldwork is needed to determine why this stream has been able to develop a meandering planform instead of the relatively straight entrenched planforms that characterize the other streams. The flood chute, between T4 and T10, may bypass the main channel if a significant knickpoint can migrate up the flood channel. Occupation of the flood chute by flood flows will greatly reduce the amount of stress that is applied to the main channel during a flood event. This reduction of energy, may explain why the surveyed reach had the second lowest bankfull area (1.15 square meters [12.38 sq ft]) and the lowest channel-full area (2.84 square meters [30.57 sq ft]; Table 20). One of the interesting landforms identified at CHAT014 was the 'floodplain' on river right between T9 and T11. The arcuate morphology of this landform suggest that it is a stabilized slump surface and not a 'traditional' constructional floodplain. Further sedimentological work is needed to determine the actual processes that created this 'floodplain.'

Large Low-Entrenchment (Third-Order) Streams

CHAT001—Haw Creek

CHAT001's watershed (8.78 square kilometers [3.39 sq mi]) is approximately half the size of CHAT0013's watershed (16.88 square kilometers [6.52 sq mi]; Table 36). Approximately 58% of Haw Creek's watershed is developed and 37% is forested (Table 37). Compared to CHAT013's watershed, CHAT001's watershed has a higher entire stream gradient (0.0146 m/m), an average segment gradient (0.0070 m/m), and a steeper reach gradient (0.0074 m/m; Tables 36 and 38). CHAT001's watershed has lower slope (7.13°), slightly lower drainage density (1.59 km/km^2), equal basin shape (0.15), and a higher basin relief ratio (0.016; Table 36). Though the low basin shape (elongated basin) likely attenuates flood flows, the other geomorphic characteristics (specifically the high entire stream gradient) coupled with the high level of development suggest Haw Creek (CHAT001) has a flashier flow regime than Long Island Creek (CHAT013). Though, gage data are needed to confirm this interpretation.

The reach surveyed on Haw Creek (CHAT001) is not frequently visited by the public. The trail head, at the bridge, leading to the site (on river right) was grown over and there was no evidence of use (i.e., no footprints) during the survey. A large and deep pool dominated the middle portion of the reach (between T7 and T9; Figure 42). In-stream habitat was 24% riffle, 17% run, and 54% pool (Table 39). The mean diameter of bed material (46.10 millimeters [1.81 in]) was significantly coarser than CHAT013 (Table 40). The coarse bed material was likely a result of the steeper entire stream gradient, segment gradient, and longitudinal profile at CHAT001 compared to CHAT013. The reach had approximately half the number of pieces of LWD (n = 16) as CHAT013 but nearly the same volume per channel area (0.0015 m^3/m^2; Table 42). While pool habitats dominated the reach, the coarse bed material and the presence of the riffle areas are generally indicative of a healthy environment with a diversity of habitats (Allan and Castillo 2007; Palmer et al. 2010). Based on the GCU, bed sediment, and LWD within the reach, CHAT001's instream habitat was classified as "good." This classification is a generalized interpretation of in-stream habitat and additional work is needed to determine how flow (e.g., flashiness of flow and baseflow conditions), water quality, and in-stream physical characteristics affect biodiversity and stream health at CHAT001. The habitat classification at CHAT001 may be downgraded to "fair" if there is an increase in fine bed material deposited within the reach, or if LWD and GCU diversity decrease. Alternatively, the addition of stable (non-mobile) in-channel LWD will enhance habitat diversity and continue to support a classification of "good" (Allan and Castillo 2007).

The major defining characteristics of the stream were the high occurrence of multiple surfaces (i.e., floodplains, low terraces) inset within the higher (historical terrace) and the presence of flood chutes on the lower surfaces. The surveyed reach on Haw Creek had very low sinuosity (1.07; Table 38) but the position of the thalweg was quite variable (CV = 0.58; Table 44). The stream has developed a meandering planform inset within the higher terrace and multiple surfaces are available for flood waters to inundate (Figure 42). Additionally, multiple flood chutes were observed (e.g., on detailed transects 1 and 3; Figure 44) that further reduce the erosive power flooding has on the main channel. The average channel-full area of this section of Haw Creek (41.40 square meters [445.63 sq ft]) was much greater than CHAT013's channel-full area (26.27 square meters [282.77 sq ft]; Table 38). The reason why channel-full area is greater is because of the floodplain and low terrace surfaces found throughout the reach. These surfaces greatly increase the channel-full width of the channel leading to much greater channel-full areas in these portions of the stream.

CHAT013—Long Island Creek

CHAT013's watershed is covered by more developed land cover than forest and is approximately twice the size of CHAT001's watershed. Approximately 60% of the watershed is developed (high percent of which is medium and high intensity development) and 40% is forested (Table 37). Compared to CHAT001, CHAT013's watershed has a gentler entire stream gradient (0.0065 m/m), a slightly gentler segment gradient (0.0065 m/m), and a much gentler reach gradient (0.0044 m/m; Tables 36 and 38). CHAT013's watershed has higher slope (8.71°), a lower basin relief ratio (0.010), approximately equal drainage density (1.61 km/km^2), and equal basin shape (0.15) compared to CHAT001's watershed (Table 36). While the watershed and stream network do not have a lot of relief or a high slope, the large amount of development within the watershed likely increases the

flashiness of the flow regime affecting CHAT013. Similar to CHAT001, the low basin shape likely attenuates the propagation of the flood wave through the stream network. Gage data are needed to determine the actual flow regime influencing CHAT013.

The reach surveyed on Long Island Creek (CHAT013) is frequented by visitors (e.g., trail on river right and footprints on floodplain and bar surfaces). The hiking trail on river right (between T8 and T9) was being actively undercut by the stream (Figure 45). Additionally, there was a social trail that leads to the stream from the trail near T11 (onto floodplain). The reach had a good mixture of GCUs, 46% riffle, 39% glide, and 39% pool (Table 39). Additionally, the upstream portion of the reach (between T9 and T11) had a few LWD steps creating complex habitats (Figure 45). The mean diameter of bed sediment (24.76 millimeters [0.97 in]) at CHAT013 was much finer than the bed sediment at CHAT001 (Table 40). The significant difference between bed material at CHAT013 and CHAT001 may be indicative of increased sediment delivery to CHAT013, different geologies, or due to the low network, segment, and reach gradients at CHAT013. The reach had an abundance of LWD (n =30) and a slightly higher volume of LWD per channel area (0.0019 m^3/m^2) compared to CHAT001 (Table 42). Based on the GCU, bed sediment, and LWD within the reach, CHAT013's instream habitat was classified as "fair" to "good." This classification is a generalized interpretation of in-stream habitat and additional work is needed to determine how flow (e.g., flashiness of flow and baseflow conditions), water quality, and in-stream physical characteristics affect biodiversity and stream health at CHAT013. Habitat at CHAT013 will likely continue to be "good" unless fine or very fine sediment is deposited within the reach (potentially from upstream disturbance); or if LWD decreases due to downstream transport or is buried by the relatively mobile bed sediment.

The major defining characteristics of the stream were the LWD steps between T9 and T11 and the high occurrence of sand and gravel bars throughout the reach. Thalweg depth within the reach was relatively shallow and the stream was choked with sand. This high concentration of sand had buried many pieces of LWD within the channel (see Figure 45 between T6 and T7 for an example). These pieces of LWD were potentially step features (e.g., between T9 and T11) prior to becoming buried. Steps created by LWD create a diversity of habitats thought to positively affect benthic macroinvertebrate communities. However, in-reach observations suggest that the bed is highly mobile (i.e., buried LWD steps). This shifting substrate is detrimental to benthic dwelling invertebrates (Allan and Castillo 2007). Though the variability of thalweg position was low (CV = 0.26; Table 44), the presence of multiple longitudinally extensive sand and gravel bars within the reach indicates the stream is beginning to reestablish a meandering planform inset within the high terrace (Simon and Darby 1999).

Conclusion

The watersheds draining to the surveyed stream reaches at Chattahoochee River National Recreation Area ranged from small mostly forested first-order watersheds to large mostly developed third-order watersheds. Five of the watersheds were relatively steep (four first-order and one second-order watershed), five of the watersheds had average slope and relief (three second-order and both third-order watersheds), and the remaining four watersheds had relatively gentle topography (one first-order and three second-order watersheds). The majority of the watersheds (eight out of 14) had high amounts of developed land cover (one first-order, six second-order, and both third-order watersheds). One watershed (CHAT007) had approximately equal amounts of development, forest, and grassland. The remaining five watersheds were mostly forested (four first-order and one second-order). Based on the geomorphic and land cover characteristics of the watersheds, the majority of the watersheds (nine out of fourteen) likely have a flashy flow regime (three first-order, four second-order, and both third-order watersheds). The remaining five watersheds likely have less flashy flow regimes; though stream gages are needed to determine the actual flow regimes of the surveyed streams.

Based on the results of the pebble count and the type or distribution of GCU within each reach, habitat within 10 of the surveyed streams was classified as high energy (three first-order, five second-order, and both third-order streams). The habitat within the four remaining reaches was classified as low energy (two first-order and two second-order) due to a high proportion of run and pool habitats coupled with fine bed sediment. Generally, when present, large woody debris (LWD) were important for step creation and diversification of stream habitat. Given the high energy and flashy classification of many reaches, LWD serves to dissipate energy and trap fine organic material or sediment that would otherwise be transported downstream (Allan and Castillo 2007). Based on the GCUs, bed sediment, and LWD characteristics of the surveyed streams, instream habitat was classified as "good" for five streams (one first-order, three second-order, and one third order), "fair" for six streams (three first-order, one second-order, and two third-order), "fair" to "good" for one stream (second-order), and "poor" for three streams (one first-order and two second-order). These classifications are generalized interpretations of instream habitat and additional work is needed to determine how flow regime (e.g., flashiness of flow and baseflow conditions), water quality, and instream physical characteristics affect the biodiversity and stream health. Overall, habitat classification for each reach may improve if: (1) there is an increase in stable (non-mobile) in-channel (non-bridging) LWD, (2) there is a reduction in the amount of fine sediment delivered to the reach, and/or (3) habitat (GCU) diversity increases. Conversely, habitat may degrade if: (1) LWD is transported out of the reach, (2) there is an increase in the amount of fine sediment added to and stored within the bed of the stream, and/or (3) habitat diversity decreases due to the previous two mechanisms.

All stream reaches that were surveyed are recovering from a legacy of poor land use practices. Additionally, all of the streams are influenced by varying amounts of impervious surface cover and urban/suburban development in their watersheds. Four of the streams are relatively straight entrenched reaches and have little to no interaction between the in- and out-of-channel areas (except during very large events; two first-order and two second-order streams). Seven of the streams have

begun to develop a meander planform inset within the entrenched channel-full surface (one first-order, four second-order, and both third-order streams). The other three stream reaches that were surveyed have developed a meandering planform (one first-order and two second-order streams). Six of the fourteen streams are (or will soon be) dealing with the headward migration of downstream knickpoint (four first-order and two second-order streams). The rate at which these knickpoints migrate upstream is dependent on the sediment composition of the boundary layer (bed sediment), the amount of LWD available to increase bed and bank resistance, and the flashiness of the flow regime that shapes the stream. As a result of changes in bed elevation (from base level lowering or through the process of complex response), bank undercutting and slumping is a common process occurring at every stream that was surveyed. In the smaller streams, these slumps may become colonized by vegetation and become stable sediment sinks. In the large streams and in higher energy portions of the smaller streams, these slumps will likely erode and will contribute additional sediment to areas downstream.

Out of the 14 streams that were surveyed, only two have immediate management concerns (CHAT012 and CHAT013). CHAT012, Cabin Creek, is actively eroding into a hiking trail along a 4-meter (13.1-ft) section on river left. There is a LWD step immediately downstream of this area that may increase the energy available to erode the reach should it fail (potential increase in slope if LWD step breaks or is bypassed). CHAT013, Long Island Creek, is also eroding into a hiking trail that runs alongside the stream (river right). The data that were collected on these reaches will be helpful to determine the rate at each these portions of stream are eroding and will help determine the effectiveness of any management actions that are enacted.

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Appendix A. Explanation of Variables

Table A-1. Explanation of variables collected by the Wadeable Stream Habitat Monitoring Protocol including the scale at which each is collected.

Variable	Variable Scale	Description
Drainage Area	Basin	The topographical area to which precipitation, sediment, and dissolved constituents are funneled to a common outlet point along a given stream channel (Dunne and Leopold 1978).
Total Stream Length	Basin	The sum of the length of perennial streams within a watershed.
Drainage Density	Basin	The ratio of total stream length to drainage area.
Basin Length	Basin	The length of the line that bisects a watershed running from outlet to drainage divide.
Basin Shape	Basin	Drainage area divided by basin length squared (Horton 1932)
Average Watershed Slope	Basin	Within watershed, average of the slope values of each pixel of a digital elevation model.
Standard Deviation of Slope	Basin	Within watershed, standard deviation of the slope values of each pixel of a digital elevation model.
Basin Relief	Basin	Within watershed, maximum elevation minus minimum elevation
Standard Deviation of Elevation	Basin	The standard deviation of elevation within a watershed.
Basin Relief Ratio	Basin	A ratio calculated by dividing basin relief by basin length.
Entire Stream Gradient	Basin	The difference in elevation at 85% and 10% of the main stem stream length divided by the stream length between the two points (Fitzpatrick et al. 1998).
Segment Gradient	Basin	The difference in elevation between the upstream extent of the stream segment and the downstream extent of the stream segment, divided by the length of the stream segment.
Strahler Stream Order	Basin	A stream ordering system where order increases when two orders of the same magnitude join.
Bifurcation Ratio	Basin	The ratio of streams in a given Strahler order to streams in the next highest order (e.g., number of first-order streams/number of second-order streams).
Land Use/Land Cover	Basin	Land use/land cover is derived from the NLCD dataset.
Geomorphic Channel Units	Reach	Geomorphic channel units are a way to classify in-channel habitat (e.g., riffles and pools)

[1] collected at each standard transect (11 measurements).

[2] calculated at each detailed transect (3 per reach) using survey data collected using a total station.

Table A-1 (continued). Explanation of variables collected by the Wadeable Stream Habitat Monitoring Protocol including the scale at which each is collected.

Variable	Variable Scale	Description
Large Woody Debris	Reach	Pieces of woody material that have a diameter greater than 0.1 m and are 1 m or longer.
Pebble Count	Reach	The size and distribution of 100 particles (pebble count) from a representative riffle (Wolman 1954).
Canopy Closure	Reach[1]	The average of four measurements (looking upstream, downstream, and at each bank) taken using a spherical densiometer.
Reach Sinuosity	Reach	Sinuosity is calculated by dividing reach length by valley length.
Longitudinal Profile	Reach	The gradient of the line that connects the tops of the steps and riffles within a reach (channel slope)
Wetted Width	Transect[1]	Wetted channel width is measured where water is flowing (including undercuts)
Active Channel Width	Transect[1]	Active channel width is measured to the beginning of vegetation within the stream channel
Bankfull Width	Transect[1,2]	Bankfull widths should only be measured if there is a floodplain (or incipient floodplain) present
Bankfull Height	Transect[1,2]	The height of the channel bank where a floodplain is present
Bankfull Area	Transect[2]	The cross-sectional area of a stream channel at bankfull stage (height) measured perpendicular to flow
Bankfull Perimeter	Transect[2]	The length of the contact between the stream of flowing water and its containing channel, measured at a section perpendicular to streamflow at bankfull discharge
Bankfull Hydraulic Radius	Transect[2]	A measure of hydraulic efficiency defined by the ratio between bankfull area and bankfull perimeter
Channel-full Width	Transect[1,2]	Channel full widths are measured from the top of the lowest bank that is not a floodplain.
Channel-full Height	Transect[1,2]	The height of the channel bank where a floodplain is not present (channel-full height is also measured where a floodplain is inset within an entrenched channel)
Channel-full Area	Transect[2]	The cross-sectional area of a stream channel at bankfull stage measured perpendicular to flow
Channel-full Perimeter	Transect[2]	The length of the contact between the stream of flowing water and its containing channel, measured at a section perpendicular to streamflow at channel full discharge

[1] collected at each standard transect (11 measurements).

[2] calculated at each detailed transect (3 per reach) using survey data collected using a total station.

Table A-1 (continued). Explanation of variables collected by the Wadeable Stream Habitat Monitoring Protocol including the scale at which each is collected.

Variable	Variable Scale	Description
Channel-full Hydraulic Radius	Transect[2]	A measure of hydraulic efficiency defined by the ratio between channel full area and channel full perimeter
Thalweg Position	Transect[1]	The position of the thalweg as a percent distance of the wetted width from left water's edge
Thalweg Depth	Transect[1]	The greatest depth of water along a transect
Dominant Particle Size	Transect[1]	A visual estimate of the dominant sediment size along a transect
Dominant Habitat	Transect[1]	A visual estimate of the dominant geomorphic channel unit along a transect
In-channel features	Transect[1]	A description of the in-channel features (e.g., bars or islands) that are present along a transect
Floodplain width	Transect[1]	The width(s) of floodplain(s) present along rivers left and/or right
Bank Undercut	Transect[1]	Where the bank overhangs the channel due to lateral erosion at the base of the bank
Bank Angle	Transect[1]	The dominant bank angle from active channel boundary to the top of the bank
Bank Sediment	Transect[1]	The dominant sediment composition of the channel banks
Bank Erosion	Transect[1]	The presence of and type erosion (e.g., lateral or slump) that is observed on the channel banks
Bank Cover	Transect[1]	A visual estimate of the percent of the channel banks that has vegetative cover

[1] collected at each standard transect (11 measurements).

[2] calculated at each detailed transect (3 per reach) using survey data collected using a total station.

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Appendix B. Survey Results for CHAT002

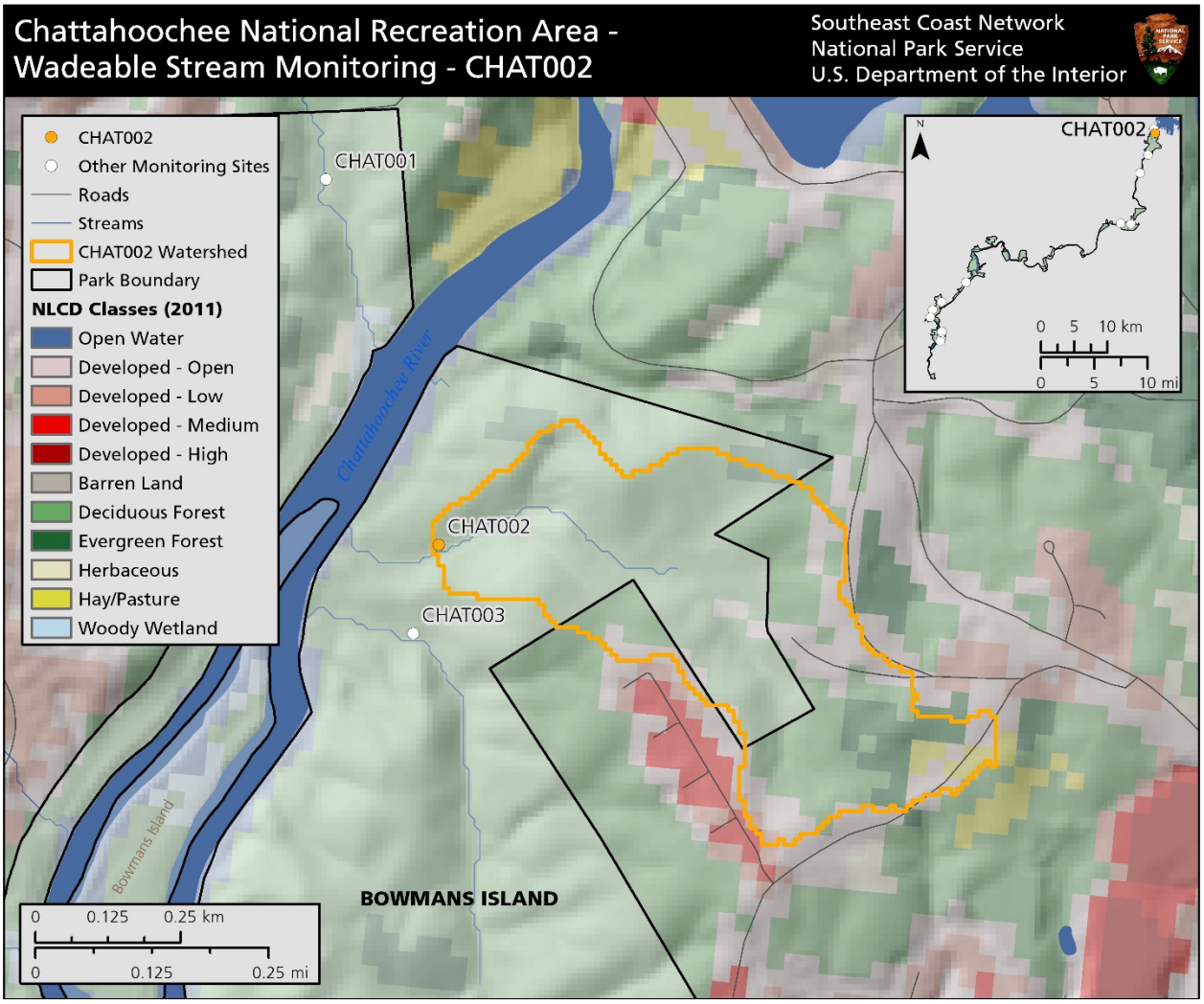


Figure B-1. Map showing the watershed draining to CHAT002 at Chattahoochee National Recreation Area. The land use/land cover (NLCD 2011 data set; Homer et al. 2015), road network (USCB 2011), and perennial streams (derived from a 10-meter [32.8-feet] digital elevation model; data available from the U.S. Geological Survey) in the vicinity of the park are also shown.



Figure B-2. Photograph taken on CHAT002 looking upstream from T2 (detailed transect 1).



Figure B-3. Photograph taken on CHAT002 looking downstream from T2 (detailed transect 1).



Figure B-4. Photograph taken on CHAT002 looking at the left bank from T2 (detailed transect 1).



Figure B-5. Photograph taken on CHAT002 looking at the right bank from T2 (detailed transect 1).



Figure B-6. Photograph taken on CHAT002 looking upstream from T6 (detailed transect 2).



Figure B-7. Photograph taken on CHAT002 looking downstream from T6 (detailed transect 2).



Figure B-8. Photograph taken on CHAT002 looking at the left bank from T6 (detailed transect 2).



Figure B-9. Photograph taken on CHAT002 looking at the right bank from T6 (detailed transect 2).



Figure B-10. Photograph taken on CHAT002 looking upstream from T10 (detailed transect 3).



Figure B-11. Photograph taken on CHAT002 looking downstream from T10 (detailed transect 3).



Figure B-12. Photograph taken on CHAT002 looking at the left bank from T10 (detailed transect 3).



Figure B-13. Photograph taken on CHAT002 looking at the right bank from T10 (detailed transect 3).

Table B-1. Land use/land cover characteristics for 2001, 2006, and 2011 for CHAT002. The data included in this table are from the National Land Cover Dataset (Fry et al. 2001; Homer et al. 2006; Homer et al. 2015).

NLCD Class	2001 percent of watershed	2006 percent of watershed	2011 percent of watershed
Open Water	0	0	0
Developed—Open[1]	12	16	17
Developed—Low[1]	0	1	1
Developed—Medium[1]	0	1	0
Developed—High[1]	0	0	0
Barren	0	0	0
Deciduous	77	74	74
Evergreen	9	6	6
Mixed Forest	0	0	0
Shrub	0	0	0
Grassland	0	0	0
Pasture	2	2	2
Cultivated	0	0	0
Woody Wetland	0	0	0
Herbaceous Wetland	0	0	0

[1] refers to the intensity or type of development.

Table B-2. Geomorphic channel units (GCU) observed in the area between transects at CHAT002. The data describe the percent coverage of each type of GCU [SD—Standard deviation].

Transect	(%) Riffle	(%) Run	(%) Glide	(%) Pool	(%) Step
1–2	100	0	0	0	0
2–3	75	0	0	25	0
3–4	40	0	0	60	0
4–5	40	0	0	60	0
5–6	50	0	0	50	0
6–7	90	10	0	0	0

Table B-2 (continued). Geomorphic channel units (GCU) observed in the area between transects at CHAT002. The data describe the percent coverage of each type of GCU [SD—Standard deviation].

Transect	(%) Riffle	(%) Run	(%) Glide	(%) Pool	(%) Step
7–8	0	0	0	100	0
8–9	100	0	0	0	0
9–10	50	50	0	0	0
10–11	40	60	0	0	0
Frequency	9	3	0	5	0
Max (%)	100	60	0	100	0
Mean (%)	59	12	0	30	0
Median (%)	50	0	0	13	0
SD (%)	32	23	0	36	0

Table B-3. Characteristics of the large woody debris (LWD) observed at CHAT002 [m—meter].

LWD ID	Length (m)	Diameter (m)	Volume (m^3)	Transect Interval	Function	Position
1	4.84	0.64	1.56	8	Organic trap, Sediment trap	Bridge
2	4.00	0.37	0.43	4	None	Bridge
3	1.20	0.13	0.02	4	Jam	Buried
4	2.73	0.10	0.02	3	None	Bridge
5	1.82	0.21	0.06	1	Pool formation, Sediment trap	Buried
6	1.86	0.19	0.05	1	None	Bridge

Table B-4. Variability of canopy cover observed at CHAT002 [SD—Standard deviation; CV—Coefficient of variation].

Transect	Canopy Cover (%)
1	99
2	96
3	97
4	99
5	99
6	94
7	96
8	94
9	96
10	91
11	96
Min (%)	91
Max (%)	99
Mean (%)	96
Median (%)	96
SD (%)	2
CV	0.02

Table B-5. Average reach-scale bank characteristics at CHAT002. [L indicates left bank and R indicates right bank; m—meters; SD—Standard deviation; CV—Coefficient of variation].

Bank Characteristics	n (L)	n (R)	Min (L)	Min (R)	Max (L)	Max (R)	Mean (L)	Mean (R)	Median (L)	Median (R)	SD (L)	SD (R)	CV (L)	CV (R)
Bank Height[1] (m)	11	11	0.56	0.77	2.30	1.13	0.98	0.94	0.85	0.91	0.47	0.11	0.48	0.11
Bankfull Height[1,2] (m)	3	2	0.37	0.29	0.41	0.45	0.38	0.37	0.37	0.37	0.02	0.11	0.06	0.31
Channel-full Height[1,2] (m)	11	11	0.61	0.85	2.34	1.27	1.04	1.00	0.93	0.95	0.47	0.12	0.45	0.12
Water Depth at Base[3] (m)	11	11	-0.12	-0.14	0.04	0.03	-0.02	-0.05	-0.02	-0.04	0.05	0.05	–	–
Bank Undercut[2] (m)	3	5	0.11	0.08	0.52	0.68	0.26	0.24	0.14	0.11	0.23	0.25	0.89	1.07
Bank Angle (o)	11	11	15	12	90	90	53	51	49	61	27	34	0.51	0.67
Vegetation Cover (%)	11	11	0	0	80	90	32	36	30	30	27	33	0.84	0.90
Bank Stability[4]	11	11	At-Risk	At-Risk	Unstable	Very Unstable	Unstable	Unstable	Unstable	Unstable	1.91	1.92	0.15	0.15

[1] above thalweg.

[2] statistics are based in the transects where the feature is present (# in parentheses).

[3] a negative number indicates base of bank is above the water surface.

[4] see Table 1 for explanation of scores.

Table B-6. Cross-sectional characteristics for detailed transect 1 at CHAT002 [m—meter].

Type	Area (m^2)	Perimeter (m)	Hydraulic Radius (m)	Width (m)	Depth (m)	Width/Depth
Bankfull	0.27	2.17	0.12	1.97	0.23	8.72
Channel-full	1.79	5.45	0.33	4.88	0.61	7.99
Bankfull and Channel-full Ratio	6.66	2.51	2.66	2.48	2.70	0.92

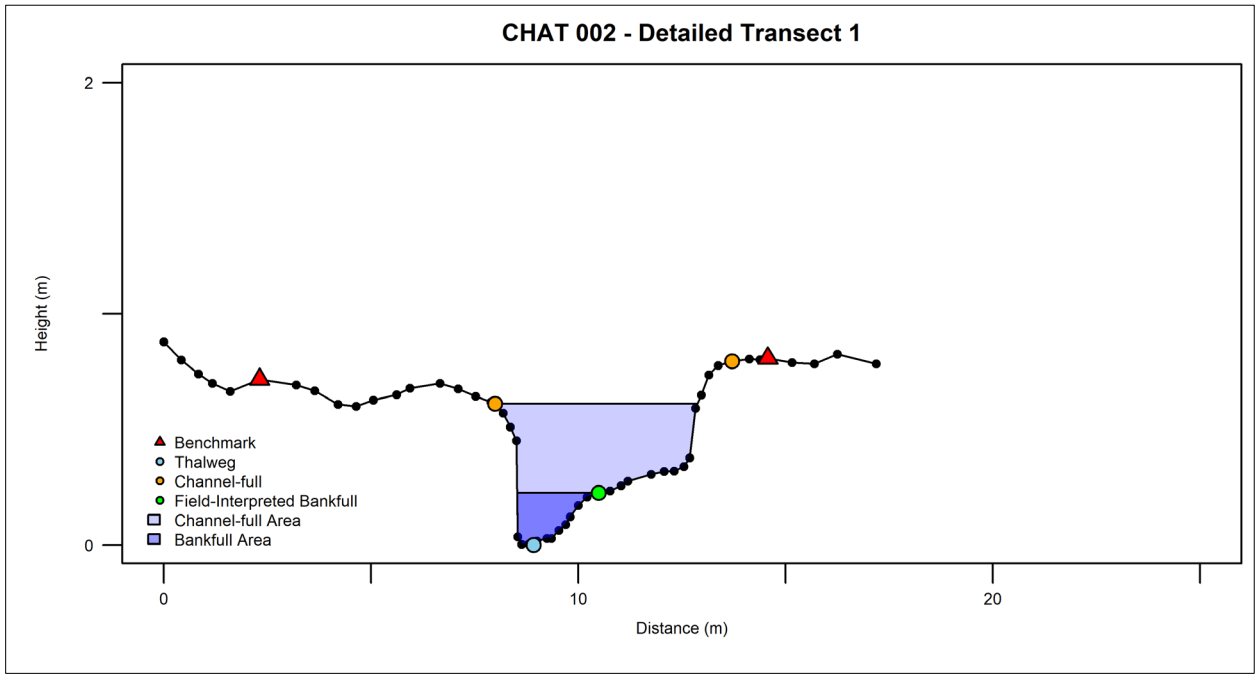


Figure B-14. Detailed transect 1 at CHAT002. The surveyed locations of the left and right benchmarks, channel-full bank-tops, and interpreted bankfull bank height are shown on the figure. Additionally, the channel-full (light blue) and bankfull (dark blue) cross-sectional areas are also included (channel-full cross-sectional area equals light blue plus dark blue).

Table B-7. Cross-sectional characteristics for detailed transect 2 at CHAT002 [m—meter].

Type	Area (m^2)	Perimeter (m)	Hydraulic Radius (m)	Width (m)	Depth (m)	Width/Depth
Bankfull	0.15	1.68	0.09	1.60	0.14	11.17
Channel-full	2.70	11.21	0.24	10.65	0.54	19.86
Bankfull and Channel-full Ratio	17.54	6.65	2.64	6.64	3.73	1.78

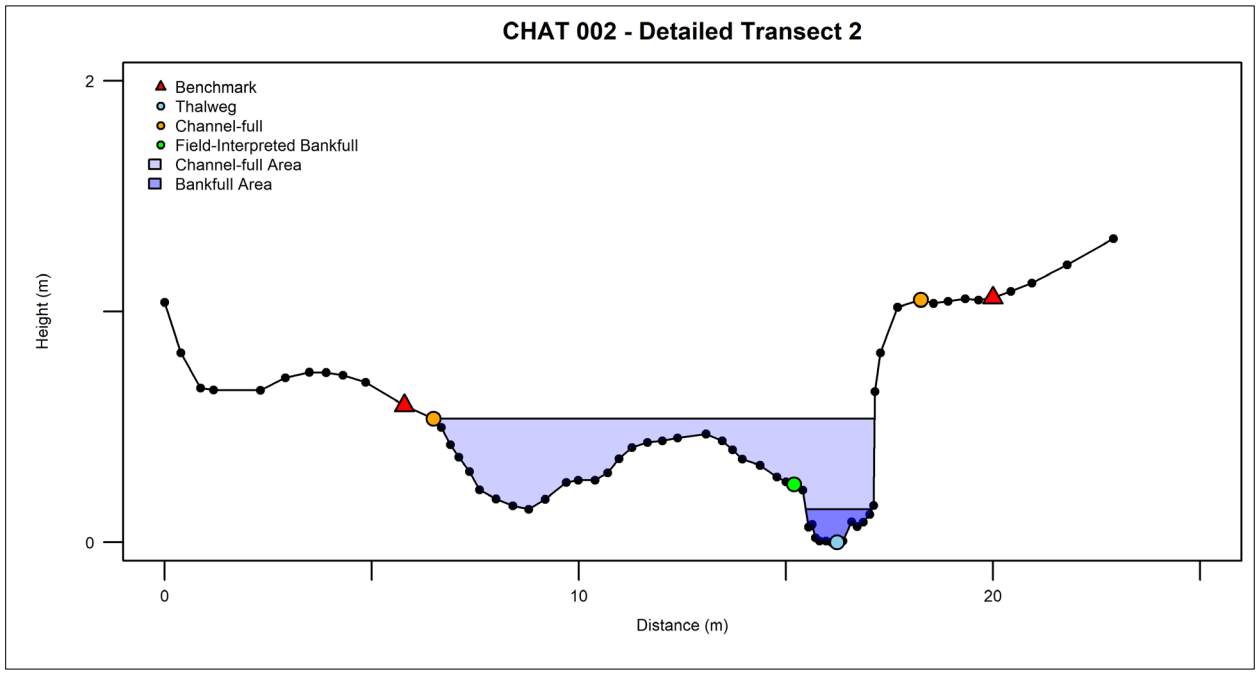


Figure B-15. Detailed transect 2 at CHAT002. The surveyed locations of the left and right benchmarks, channel-full bank-tops, and bankfull bank height are shown on the figure. Channel-full (light blue) and bankfull (dark blue) cross-sectional areas are also included (channel-full cross-sectional area equals light blue plus dark blue).

Table B-8. Cross-sectional characteristics for detailed transect 3 at CHAT002 [m—meter].

Type	Area (m^2)	Perimeter (m)	Hydraulic Radius (m)	Width (m)	Depth (m)	Width/Depth
Bankfull	0.17	2.31	0.07	2.25	0.09	25.11
Channel-full	1.89	5.09	0.37	4.62	0.63	7.31
Bankfull and Channel-full Ratio	11.45	2.20	5.20	2.05	7.05	0.29

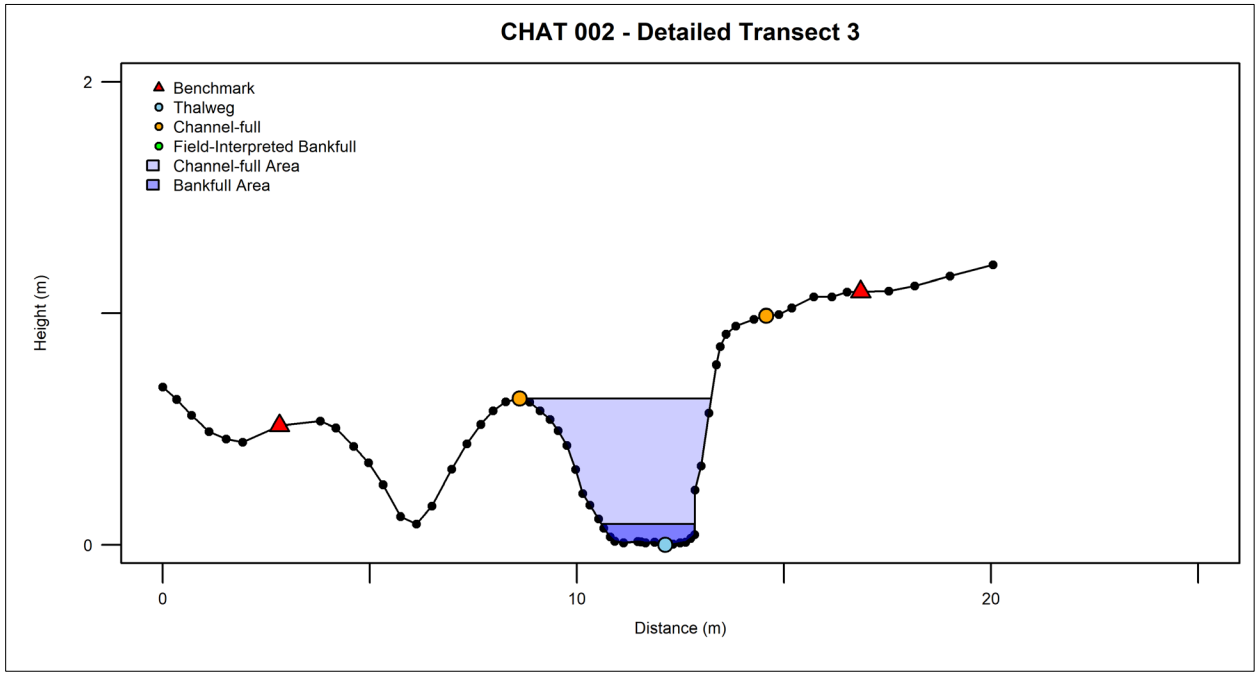


Figure B-16. Detailed transect 3 at CHAT002. The surveyed locations of the left and right benchmarks, channel-full bank-tops, and interpreted bankfull bank height are shown on the figure. Channel-full (light blue) and bankfull (dark blue) cross-sectional areas are also included (channel-full cross-sectional area equals light blue plus dark blue).

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Appendix C. Survey Results for CHAT003

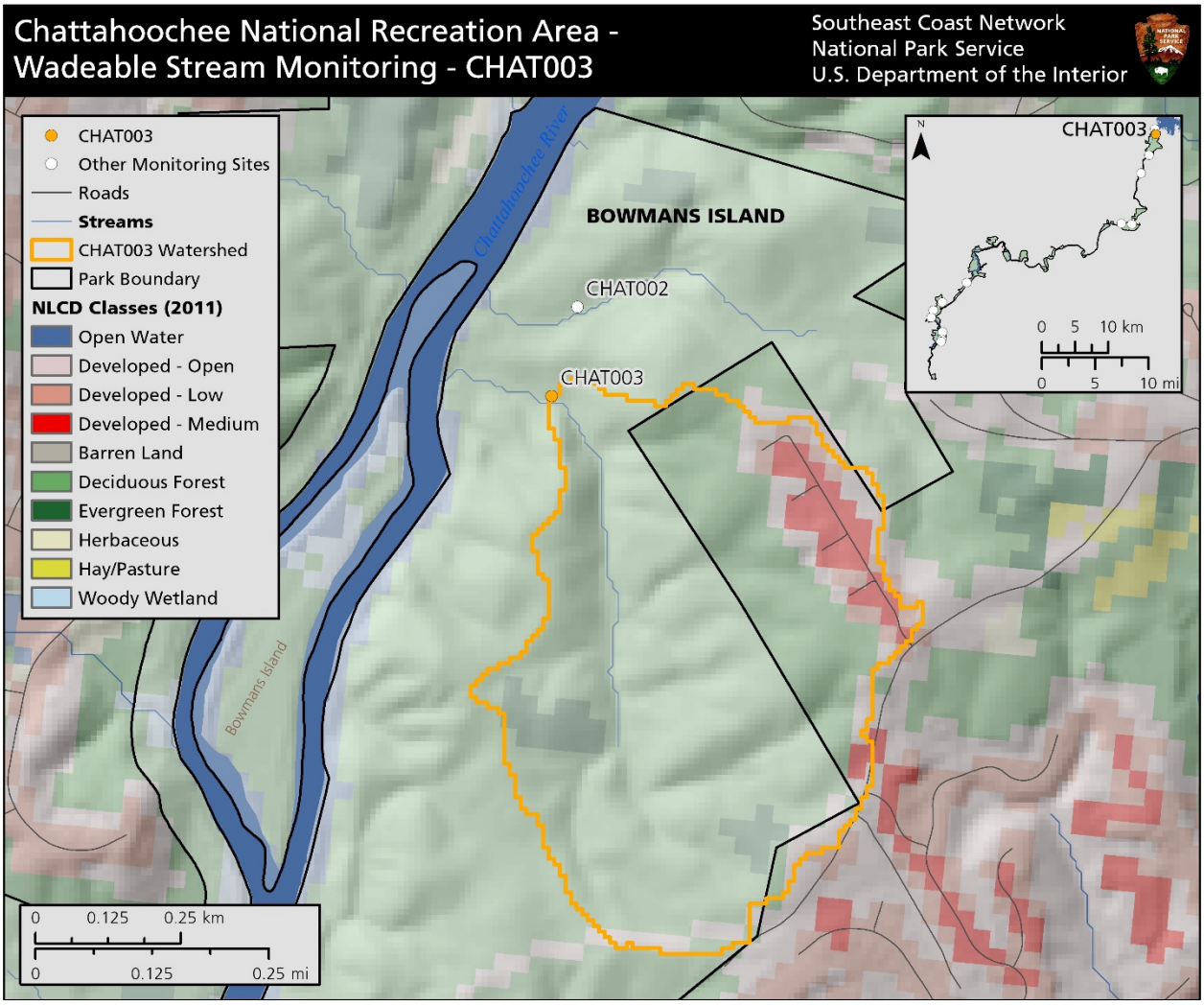


Figure C-1. Map showing the watershed draining to CHAT003 at Chattahoochee National Recreation Area. The land use/land cover (NLCD 2011, Homer et al. 2015), road network (USCB 2011), and perennial streams (derived from a 10-meter [32.8-feet] digital elevation model; data available from the U.S. Geological Survey) in the vicinity of the park are also shown.



Figure C-2. Photograph taken on CHAT003 looking upstream from T1 (detailed transect 1).



Figure C-3. Photograph taken on CHAT003 looking downstream from T1 (detailed transect 1).



Figure C-4. Photograph taken on CHAT003 looking at the left bank from T1 (detailed transect 1).



Figure C-5. Photograph taken on CHAT003 looking at the right bank from T1 (detailed transect 1).



Figure C-6. Photograph taken on CHAT003 looking upstream from T6 (detailed transect 2).



Figure C-7. Photograph taken on CHAT003 looking downstream from T6 (detailed transect 2).



Figure C-8. Photograph taken on CHAT003 looking at the left bank from T6 (detailed transect 2).



Figure C-9. Photograph taken on CHAT003 looking at the right bank from T6 (detailed transect 2).



Figure C-10. Photograph taken on CHAT003 looking upstream from T11 (detailed transect 3).



Figure C-11. Photograph taken on CHAT003 looking downstream from T11 (detailed transect 3).



Figure C-12. Photograph taken on CHAT003 looking at the left bank from T11 (detailed transect 3).



Figure C-13. Photograph taken on CHAT003 looking at the right bank from T11 (detailed transect 3).

Table C-1. Land use/land cover characteristics for 2001, 2006, and 2011 for CHAT003. The data included in this table are from the National Land Cover Dataset. (Fry et al. 2001; Homer et al. 2006; Homer et al. 2015).

NLCD Class	2001 percent of watershed	2006 percent of watershed	2011 percent of watershed
Open Water	0	0	0
Developed - Open[1]	3	7	7
Developed - Low[1]	0	4	2
Developed - Medium[1]	0	2	5
Developed - High[1]	0	0	0
Barren	0	0	0
Deciduous	84	82	82
Evergreen	12	4	4
Mixed Forest	0	0	0
Shrub	0	0	0
Grassland	0	0	0
Pasture	0	0	0
Cultivated	0	0	0
Woody Wetland	0	0	0
Herbaceous Wetland	0	0	0

[1] refers to the intensity or type of development.

Table C-2. Geomorphic channel units (GCU) observed in the area between transects at CHAT003. The data describe the percent coverage of each type of GCU [SD—Standard deviation].

Transect	(%) Riffle	(%) Run	(%) Glide	(%) Pool	(%) Step
1–2	100	0	0	0	0
2–3	50	15	0	35	0
3–4	50	0	0	50	0
4–5	90	10	0	0	0
5–6	90	10	0	0	0
6–7	100	0	0	0	0
7–8	100	0	0	0	0

Table C-2 (continued). Geomorphic channel units (GCU) observed in the area between transects at CHAT003. The data describe the percent coverage of each type of GCU [SD—Standard deviation].

Transect	(%) Riffle	(%) Run	(%) Glide	(%) Pool	(%) Step
8–9	90	0	0	10	0
9–10	80	0	0	20	0
10–11	75	15	0	10	0
Frequency	10	4	0	5	0
Max (%)	100	15	0	50	0
Mean (%)	83	5	0	13	0
Median (%)	90	0	0	5	0
SD (%)	19	7	0	18	0

Table C-3. Characteristics of the large woody debris (LWD) observed at CHAT003 [m—meter].

LWD ID	Length (m)	Diameter (m)	Volume (m^3)	Transect Interval	Function	Position
1	5.28	0.15	0.09	10	Organic trap	Bridge
2	2.66	0.09	0.02	9	Sediment trap	Buried
3	3.02	0.14	0.05	9	Sediment trap	Buried
4	3.12	0.11	0.03	9	Sediment trap, Organic trap	Buried
5	3.42	0.10	0.03	9	Bank Protection	Free
6	1.23	0.10	0.01	8	Organic trap, Bank Protection	Free
7	3.27	0.47	0.57	3	None	Bridge
8	2.00	0.65	0.66	3	Organic trap	Free
9	4.73	0.13	0.06	1	Organic trap, Sediment trap	Jam
10	2.56	0.16	0.05	1	Organic trap, Sediment trap	Jam

Table C-4. Variability of canopy cover observed at CHAT003 [SD—Standard deviation; CV—Coefficient of variation].

Transect	Canopy Cover (%)
1	87
2	90
3	85
4	94
5	91
6	91
7	96
8	93
9	88
10	90
11	96
Min (%)	85
Max (%)	96
Mean (%)	91
Median (%)	91
SD (%)	3
CV	0.04

Table C-5. Average reach-scale bank characteristics at CHAT003. [L indicates left bank and R indicates right bank; SD—Standard deviation; CV—Coefficient of variation; m—meters].

Bank Characteristics	n (L)	n (R)	Min (L)	Min (R)	Max (L)	Max (R)	Mean (L)	Mean (R)	Median (L)	Median (R)	SD (L)	SD (R)	CV (L)	CV (R)
Bank Height[1] (m)	11	11	0.54	0.65	1.25	1.06	1.00	0.87	1.04	0.88	0.18	0.14	0.18	0.16
Bankfull Height[1,2] (m)	1	2	0.24	0.23	0.24	0.51	0.24	0.37	0.24	0.37	–	0.20	–	0.54
Channel-full Height[1,2] (m)	11	11	0.63	0.71	1.39	1.31	1.09	0.97	1.11	0.97	0.20	0.18	0.19	0.19
Water Depth at Base[3] (m)	11	11	-0.06	-0.09	0.01	0.02	-0.02	-0.03	-0.03	-0.02	0.02	0.03	–	–
Bank Undercut[2] (m)	4	3	0.12	0.15	0.53	0.26	0.29	0.19	0.25	0.17	0.18	0.06	0.64	0.30
Bank Angle (°)	11	11	27	30	97	87	69	62	71	69	19	20	0.28	0.32
Vegetation Cover (%)	11	11	10	5	70	90	34	51	20	60	23	35	0.68	0.69
Bank Stability[4]	11	11	At-Risk	Unstable	Very Unstable	Unstable	Unstable	Unstable	Unstable	Unstable	1.75	1.68	0.13	0.13

[1] above thalweg.

[2] statistics are based on the transects where feature is present (# in parentheses).

[3] a negative number indicates base of bank is above the water surface.

[4] see Table 1 for explanation of scores.

Table C-6. Cross-sectional characteristics for detailed transect 1 at CHAT003 [m—meter].

Type	Area (m^2)	Perimeter (m)	Hydraulic Radius (m)	Width (m)	Depth (m)	Width/Depth
Bankfull	1.21	4.48	0.27	4.15	0.49	8.40
Channel-full	5.51	8.64	0.64	7.56	1.20	6.30
Bankfull and Channel-full Ratio	4.54	1.93	2.36	1.82	2.43	0.75

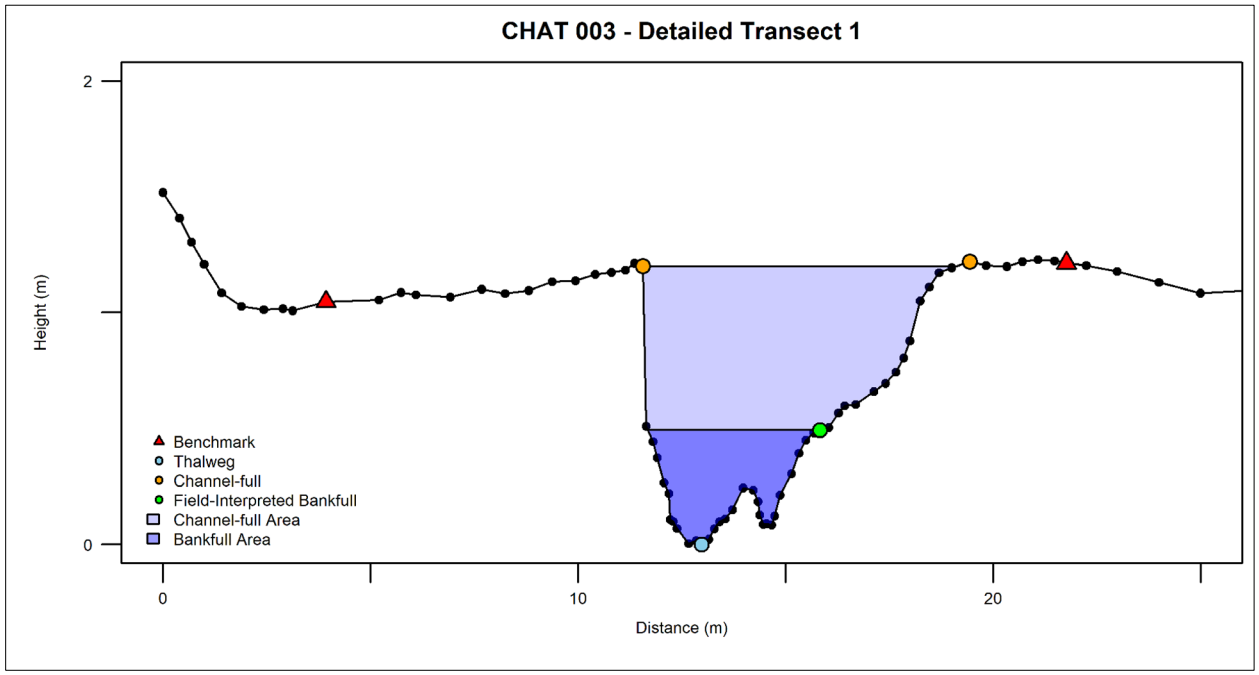


Figure C-14. Detailed transect 1 at CHAT003. The surveyed locations of the left and right benchmarks, channel-full bank-tops, and interpreted bankfull bank height are shown on the figure. Additionally, the channel-full (light blue) and bankfull (dark blue) cross-sectional areas are also included (channel-full cross-sectional area equals light blue plus dark blue).

Table C-7. Cross-sectional characteristics for detailed transect 2 at CHAT003 [m—meter].

Type	Area (m^2)	Perimeter (m)	Hydraulic Radius (m)	Width (m)	Depth (m)	Width/Depth
Bankfull	0.55	3.19	0.17	2.93	0.24	12.19
Channel-full	2.87	5.96	0.48	5.17	0.88	5.87
Bankfull and Channel-full Ratio	5.24	1.87	2.81	1.77	3.66	0.48

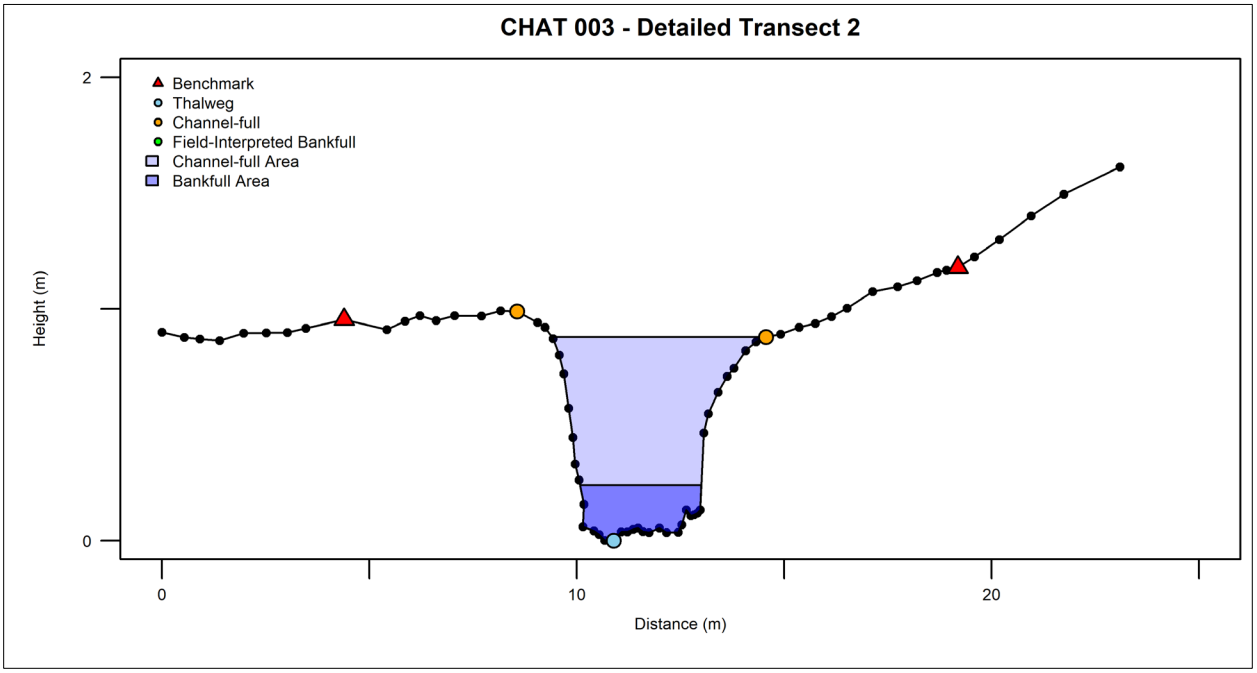


Figure C-15. Detailed transect 2 at CHAT003. The surveyed locations of the left and right benchmarks, channel-full bank-tops, and bankfull bank height are shown on the figure. Channel-full (light blue) and bankfull (dark blue) cross-sectional areas are also included (channel-full cross-sectional area equals light blue plus dark blue).

Table C-8. Cross-sectional characteristics for detailed transect 3 at CHAT003 [m—meter].

Type	Area (m^2)	Perimeter (m)	Hydraulic Radius (m)	Width (m)	Depth (m)	Width/Depth
Bankfull	0.43	2.37	0.18	2.11	0.24	8.80
Channel-full	3.40	7.21	0.47	6.47	1.06	6.10
Bankfull and Channel-full Ratio	7.99	3.05	2.62	3.06	4.42	0.69

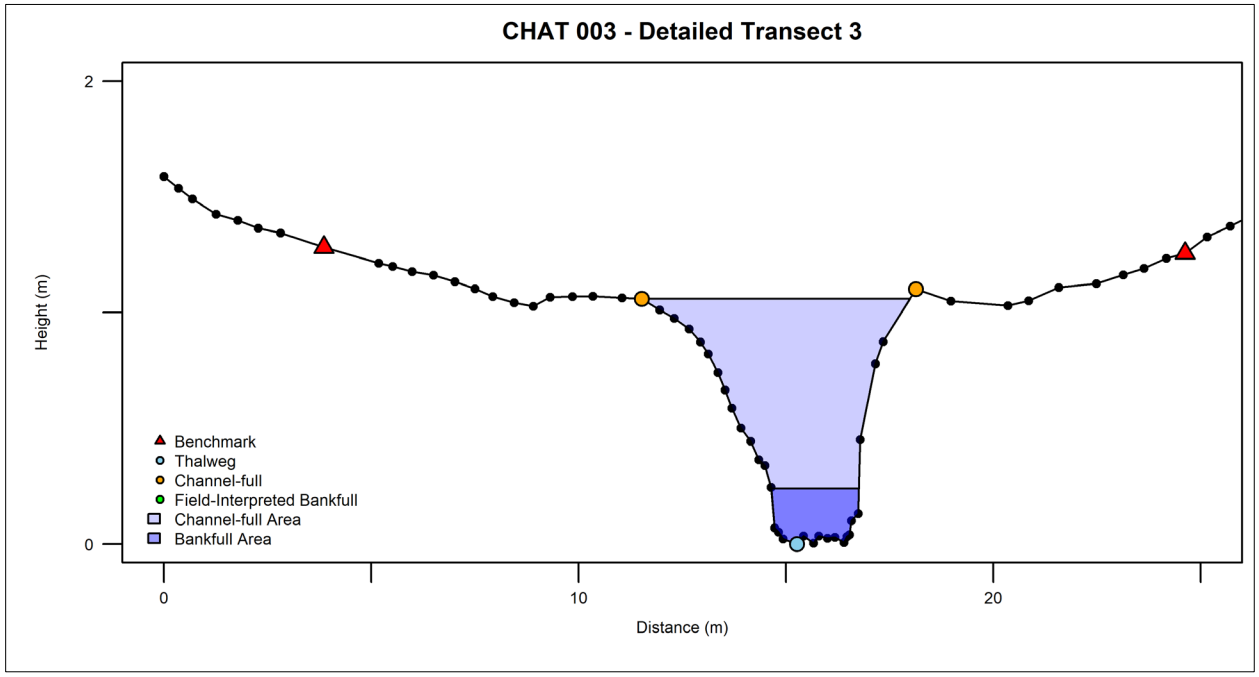


Figure C-16. Detailed transect 3 at CHAT003. The surveyed locations of the left and right benchmarks, channel-full bank-tops, and interpreted bankfull bank height are shown on the figure. Channel-full (light blue) and bankfull (dark blue) cross-sectional areas are also included (channel-full cross-sectional area equals light blue plus dark blue).

Literature Cited

Fry, J. A., G. Xian, S. Jin, J. A. Dewitz, C. G. Homer, L. Yang, C. A. Barnes, N. D. Herold, J. D. Wickham. 2006. Completion of the 2006 National Land Cover Database for the conterminous United States: Photogrammetric Engineering and Remote Sensing, v. 77, no. 9, p. 858–864.

Homer, C. G., J. A. Dewitz, J. A. Fry, M. J. Coan, S. M. Hossain, L. Nazmul, R. Charles, N. Herold, A. McKerrow, J. N Van Driel, J. Wickham. 2001. Completion of the 2001 National Land Cover Database for the conterminous United States: Photogrammetric Engineering and Remote Sensing, v. 73, no. 4, p. 337–341.

Homer, C. G., J. A. Dewitz, L. Yang, S. Jin, P. Danielson, G. Xian, J. Coulston, N. D. Herold, J. D. Wickham, and K. Megown. 2015. Completion of the 2011 national land cover database for the conterminous United States—representing a decade of land cover change information. Photogrammetric Engineering and Remote Sensing. 81:345–354.

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Appendix D. Survey Results for CHAT006

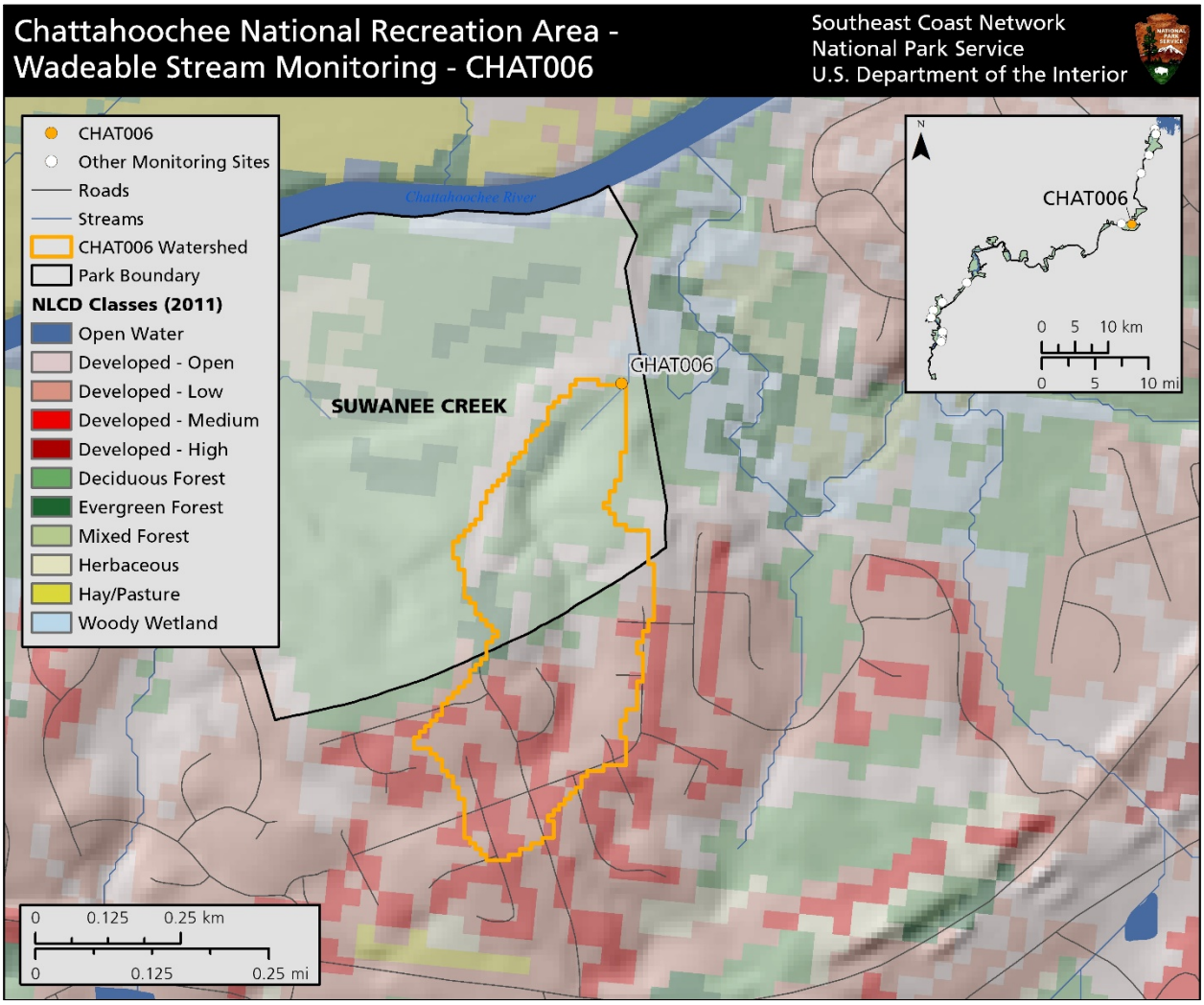


Figure D-1. Map showing the watershed draining to CHAT006 at Chattahoochee National Recreation Area. The land use/land cover (NLCD 2011, Homer et al. 2015), road network (USCB 2011), and perennial streams (derived from a 10-meter [32.8-feet] digital elevation model; data available from the U.S. Geological Survey) in the vicinity of the park are also shown.



Figure D-2. Photograph taken on CHAT006 looking upstream from T1 (detailed transect 1).



Figure D-3. Photograph taken on CHAT006 looking downstream from T1 (detailed transect 1).



Figure D-4. Photograph taken on CHAT006 looking at the left bank from T1 (detailed transect 1).



Figure D-5. Photograph taken on CHAT006 looking at the right bank from T1 (detailed transect 1).



Figure D-6. Photograph taken on CHAT006 looking upstream from T6 (detailed transect 2).



Figure D-7. Photograph taken on CHAT006 looking downstream from T6 (detailed transect 2).



Figure D-8. Photograph taken on CHAT006 looking at the left bank from T6 (detailed transect 2).



Figure D-9. Photograph taken on CHAT006 looking at the right bank from T6 (detailed transect 2).



Figure D-10. Photograph taken on CHAT006 looking upstream from T11 (detailed transect 3).



Figure D-11. Photograph taken on CHAT00 looking downstream from T11 (detailed transect 3).



Figure D-12. Photograph taken on CHAT006 looking at the left bank from T11 (detailed transect 3).



Figure D-13. Photograph taken on CHAT006 looking at the right bank from T11 (detailed transect 3).

Table D-1. Land use/land cover characteristics for 2001, 2006, and 2011 for CHAT006. The data included in this table are from the National Land Cover Dataset (Fry et al. 2001; Homer et al. 2006; Homer et al. 2015).

NLCD Class	2001 percent of watershed	2006 percent of watershed	2011 percent of watershed
Open Water	0	0	0
Developed - Open[1]	15	15	15
Developed - Low[1]	31	31	31
Developed - Medium[1]	16	16	16
Developed - High[1]	0	0	0
Barren	0	0	0
Deciduous	31	31	31
Evergreen	6	6	6
Mixed Forest	0	0	0
Shrub	0	0	0
Grassland	0	0	0
Pasture	0	0	0
Cultivated	0	0	0
Woody Wetland	0	0	0
Herbaceous Wetland	0	0	0

[1] refers to the intensity or type of development.

Table D-2. Geomorphic channel units (GCU) observed in the area between transects at CHAT006. The data describe the percent coverage of each type of GCU [SD—Standard deviation].

Transect	(%) Riffle	(%) Run	(%) Glide	(%) Pool	(%) Step
1–2	50	30	0	20	0
2–3	0	0	0	100	0
3–4	40	0	0	20	40
4–5	20	0	0	80	0
5–6	20	0	0	80	0
6–7	34	33	0	33	0

Table D-2 (continued). Geomorphic channel units (GCU) observed in the area between transects at CHAT006. The data describe the percent coverage of each type of GCU [SD—Standard deviation].

Transect	(%) Riffle	(%) Run	(%) Glide	(%) Pool	(%) Step
7–8	0	60	0	40	0
8–9	90	0	0	10	0
9–10	0	0	0	100	0
10–11	0	0	0	100	0
Frequency	6	3	0	10	1
Max (%)	90	60	0	100	40
Mean (%)	25	12	0	58	4
Median (%)	20	0	0	60	0
SD (%)	29	21	0	37	13

Table D-3. Characteristics of the large woody debris (LWD) observed at CHAT006 [m—meter].

LWD ID	Length (m)	Diameter (m)	Volume (m^3)	Transect Interval	Function	Position
1	1.10	0.22	0.04	3	Jam, Organic trap	Jam
2	1.10	0.19	0.03	3	Jam, Organic trap	Jam

Table D-4. Variability of canopy cover observed at CHAT006 [SD—Standard deviation; CV—Coefficient of variation].

Transect	Canopy Cover (%)
1	90
2	90
3	90
4	90
5	91
6	91
7	87
8	88
9	90
10	87
11	91
Min (%)	87
Max (%)	91
Mean (%)	89
Median (%)	90
SD (%)	2
CV	0.02

Table D-5. Average reach-scale bank characteristics at CHAT006. [L indicates left bank and R indicates right bank; m—meters; SD—Standard deviation; CV—Coefficient of variation].

Bank Characteristics	n (L)	n (R)	Min (L)	Min (R)	Max (L)	Max (R)	Mean (L)	Mean (R)	Median (L)	Median (R)	SD (L)	SD (R)	CV (L)	CV (R)
Bank Height[1] (m)	11	11	0.40	0.48	0.67	0.75	0.54	0.58	0.53	0.56	0.10	0.08	0.18	0.14
Bankfull Height[1,2] (m)	6	8	0.34	0.34	0.55	0.54	0.46	0.44	0.46	0.44	0.07	0.09	0.15	0.20
Channel-full Height[1,2] (m)	11	11	0.43	0.53	0.80	0.84	0.66	0.69	0.66	0.71	0.10	0.09	0.16	0.13
Water Depth at Base[3] (m)	11	11	-0.07	-0.10	0.21	0.10	0.01	-0.01	-0.02	-0.02	0.09	0.06	–	–
Bank Undercut[2] (m)	2	2	0.09	0.07	0.13	0.20	0.11	0.14	0.11	0.14	0.03	0.09	0.26	0.68
Bank Angle (°)	11	11	11	11	84	88	49	39	50	30	22	27	0.45	0.69
Vegetation Cover (%)	11	11	0	0	25	50	12	10	10	5	9	14	0.76	1.36
Bank Stability[4]	11	11	Unstable	Unstable	Very Unstable	Very Unstable	Unstable	Unstable	Unstable	Unstable	1.36	1.66	0.10	0.12

[1] above thalweg.

[2] statistics are based on the transects where feature is present (# in parentheses).

[3] a negative number indicates base of bank is above the water surface.

[4] see Table 1 for explanation of scores.

Table D-6. Cross-sectional characteristics for detailed transect 1 at CHAT006 [m—meter].

Type	Area (m^2)	Perimeter (m)	Hydraulic Radius (m)	Width (m)	Depth (m)	Width/Depth
Bankfull	0.48	2.12	0.23	1.84	0.45	4.10
Channel-full	0.87	3.55	0.24	3.22	0.61	5.26
Bankfull and Channel–full Ratio	1.79	1.67	1.07	1.75	1.36	1.28

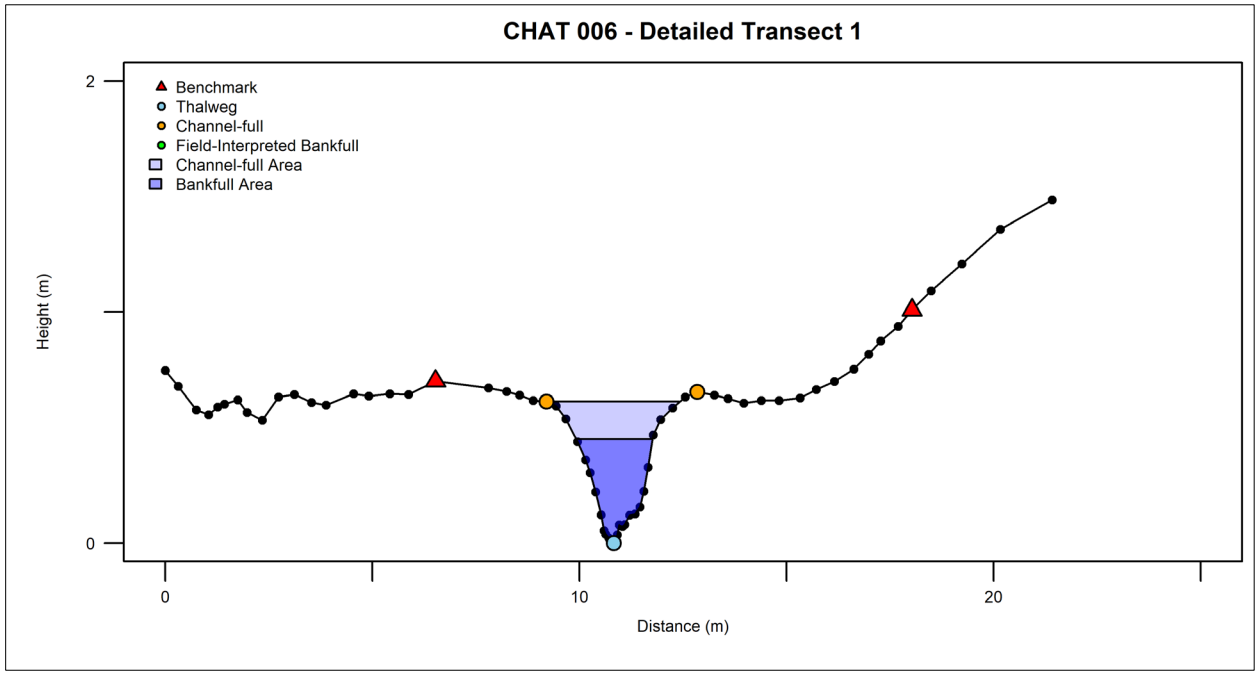


Figure D-14. Detailed transect 1 at CHAT006. The surveyed locations of the left and right benchmarks, channel-full bank-tops, and interpreted bankfull bank height are shown on the figure. Additionally, the channel-full (light blue) and bankfull (dark blue) cross-sectional areas are also included (channel-full cross-sectional area equals light blue plus dark blue).

Table D7. Cross-sectional characteristics for detailed transect 2 at CHAT006 [m—meter].

Type	Area (m^2)	Perimeter (m)	Hydraulic Radius (m)	Width (m)	Depth (m)	Width/Depth
Bankfull	0.41	2.27	0.18	2.13	0.35	6.12
Channel-full	3.70	14.26	0.26	14.02	0.66	21.09
Bankfull and Channel–full Ratio	9.04	6.28	1.44	6.59	1.91	3.45

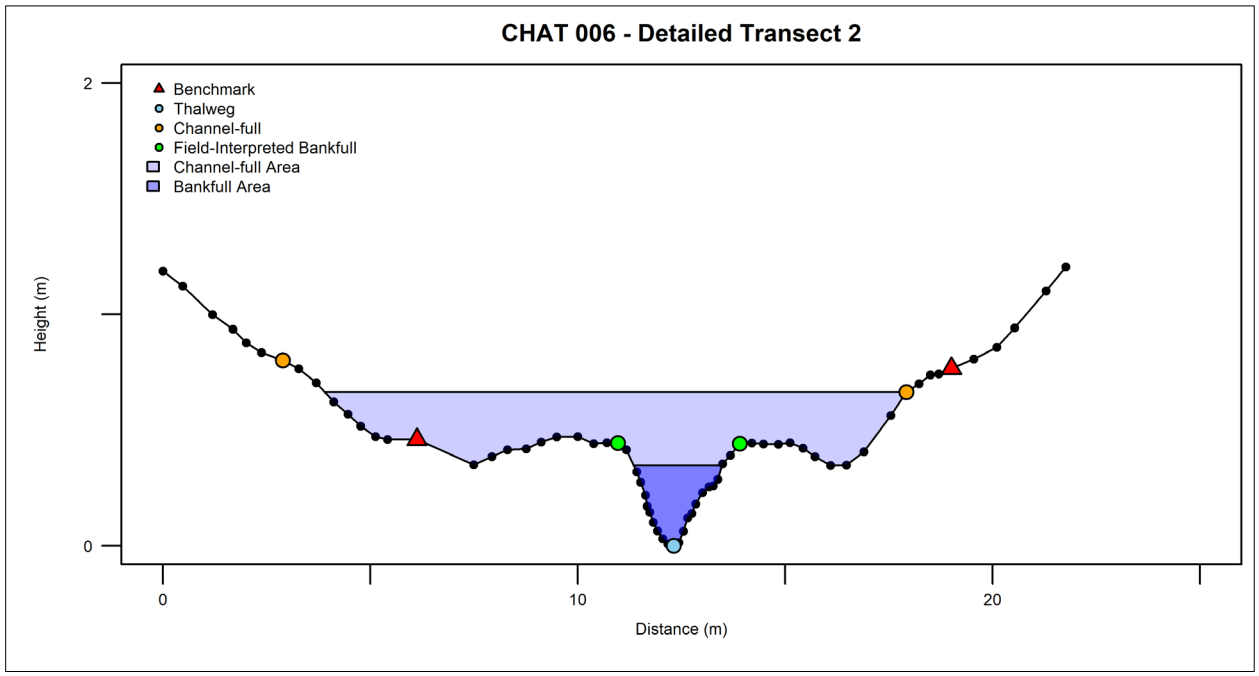


Figure D-15. Detailed transect 2 at CHAT006. The surveyed locations of the left and right benchmarks, channel-full bank-tops, and bankfull bank height are shown on the figure. Channel-full (light blue) and bankfull (dark blue) cross-sectional areas are also included (channel-full cross-sectional area equals light blue plus dark blue).

Table D-8. Cross-sectional characteristics for detailed transect 3 at CHAT006 [m—meter].

Type	Area (m^2)	Perimeter (m)	Hydraulic Radius (m)	Width (m)	Depth (m)	Width/Depth
Bankfull	0.72	3.08	0.23	2.87	0.38	7.52
Channel-full	2.31	14.34	0.16	14.06	0.55	25.46
Bankfull and Channel–full Ratio	3.23	4.65	0.69	4.89	1.44	3.39

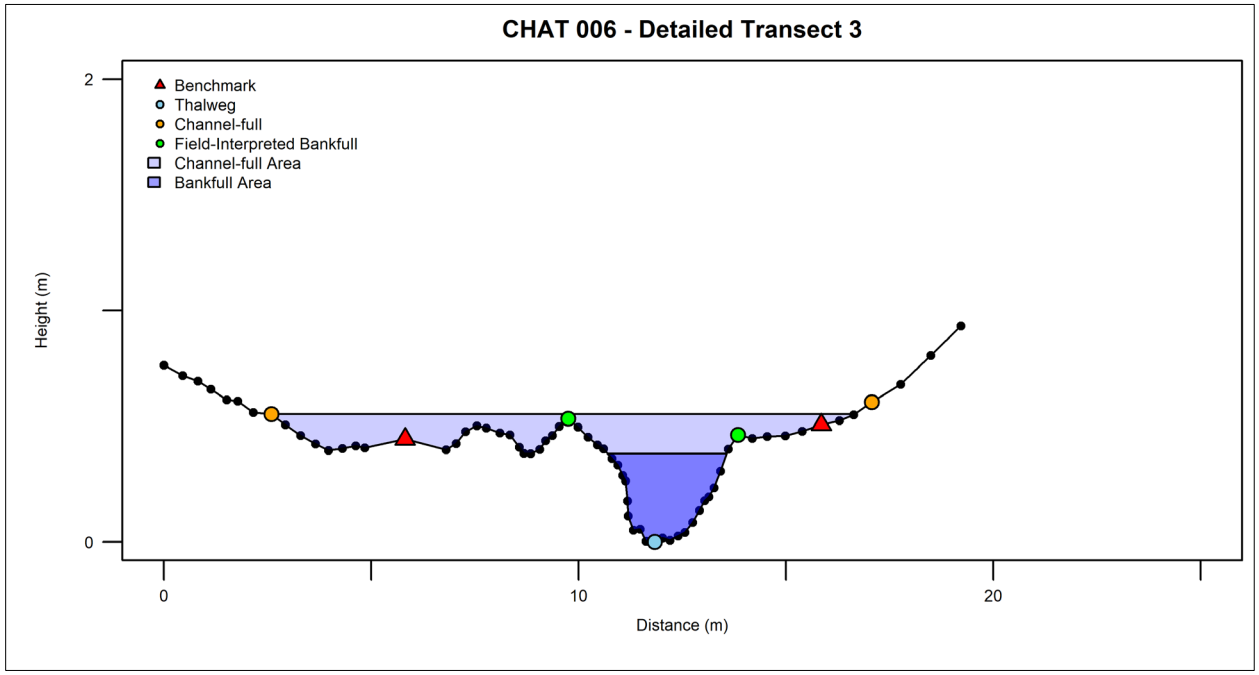


Figure D-16. Detailed transect 3 at CHAT006. The surveyed locations of the left and right benchmarks, channel-full bank-tops, and interpreted bankfull bank height are shown on the figure. Channel-full (light blue) and bankfull (dark blue) cross-sectional areas are also included (channel-full cross-sectional area equals light blue plus dark blue).

Literature Cited

Fry, J. A., G. Xian, S. Jin, J. A. Dewitz, C. G. Homer, L. Yang, C. A. Barnes, N. D. Herold, J. D. Wickham. 2006. Completion of the 2006 National Land Cover Database for the conterminous United States: Photogrammetric Engineering and Remote Sensing, v. 77, no. 9, p. 858–864.

Homer, C. G., J. A. Dewitz, J. A. Fry, M. J. Coan, S. M. Hossain, L. Nazmul, R. Charles, N. Herold, A. McKerrow, J. N Van Driel, J. Wickham. 2001. Completion of the 2001 National Land Cover Database for the conterminous United States: Photogrammetric Engineering and Remote Sensing, v. 73, no. 4, p. 337–341.

Homer, C. G., J. A. Dewitz, L. Yang, S. Jin, P. Danielson, G. Xian, J. Coulston, N. D. Herold, J. D. Wickham, and K. Megown. 2015. Completion of the 2011 national land cover database for the conterminous United States—representing a decade of land cover change information. Photogrammetric Engineering and Remote Sensing. 81:345–354.

United States Census Bureau (USCB). 2011. TIGER/Line Shapefiles-all roads, county-based. Available at https://www.census.gov/geographies/mapping-files/time-series/geo/tiger-line-file.2011.html (last accessed September 2019).

Appendix E. Survey Results for CHAT009

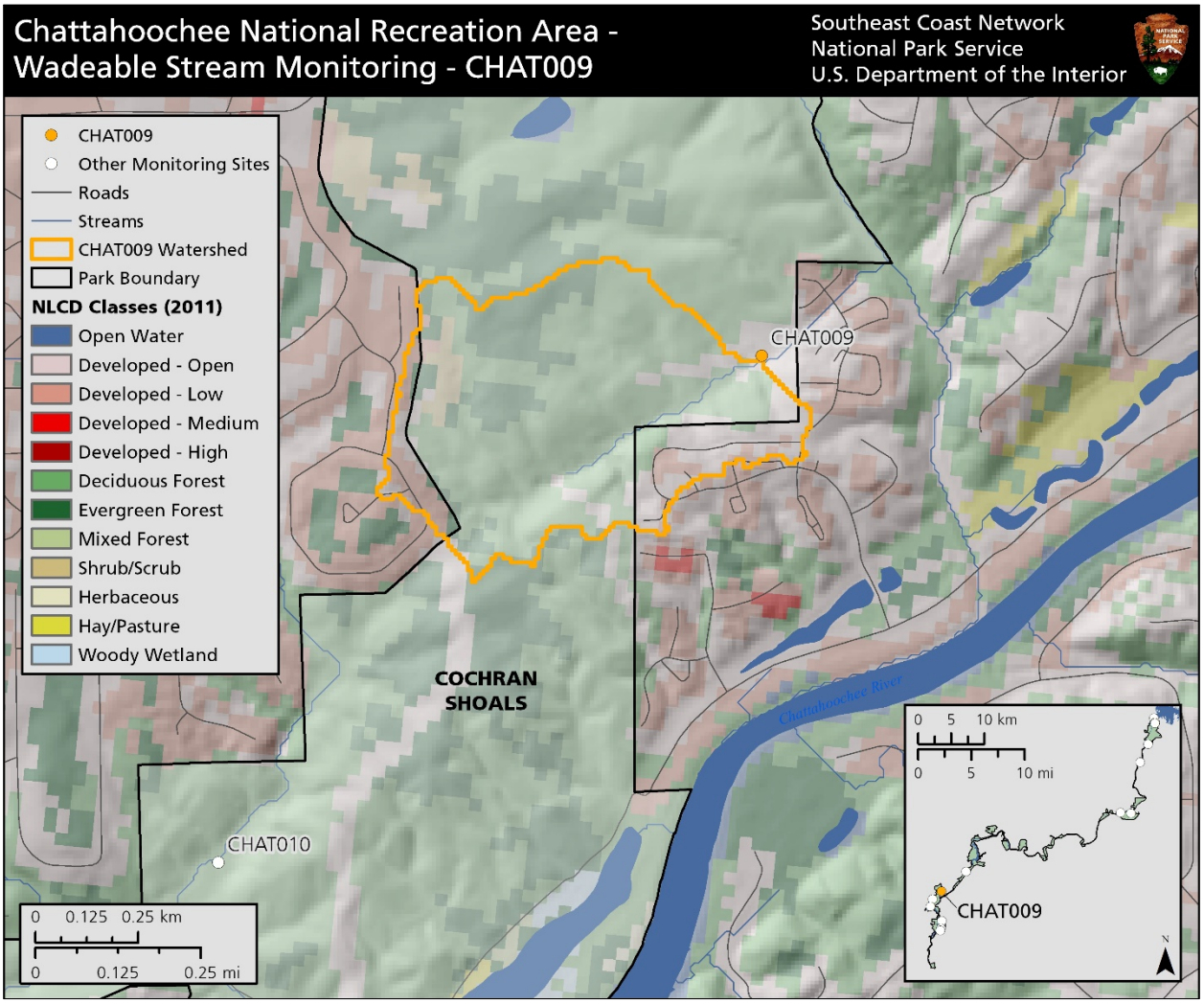


Figure E-1. Map showing the watershed draining to CHAT009 at Chattahoochee National Recreation Area. The land use/land cover (NLCD 2011, Homer et al. 2015), road network (USCB 2011), and perennial streams (derived from a 10-meter [32.8 feet] digital elevation model; data available from the U.S. Geological Survey) in the vicinity of the park are also shown.



Figure E-2. Photograph taken on CHAT009 looking upstream from T3 (detailed transect 1).



Figure E-3. Photograph taken on CHAT009 looking downstream from T3 (detailed transect 1).



Figure E-4. Photograph taken on CHAT009 looking at the left bank from T3 (detailed transect 1).



Figure E-5. Photograph taken on CHAT009 looking at the right bank from T3 (detailed transect 1).



Figure E-6. Photograph taken on CHAT009 looking upstream from T7 (detailed transect 2).



Figure E-7. Photograph taken on CHAT009 looking downstream from T7 (detailed transect 2).



Figure E-8. Photograph taken on CHAT009 looking at the left bank from T7 (detailed transect 2).



Figure E-9. Photograph taken on CHAT009 looking at the right bank from T7 (detailed transect 2).



Figure E-10. Photograph taken on CHAT009 looking upstream from T11 (detailed transect 3).



Figure E11. Photograph taken on CHAT009 looking downstream from T11 (detailed transect 3).



Figure E-12. Photograph taken on CHAT009 looking at the left bank from T11 (detailed transect 3).



Figure E13. Photograph taken on CHAT009 looking at the right bank from T11 (detailed transect 3).

Table E-1. Land use/land cover characteristics for 2001, 2006, and 2011 for CHAT009. The data included in this table are from the National Land Cover Dataset (Fry et al. 2001; Homer et al. 2006; Homer et al. 2015).

NLCD Class	2001 percent of watershed	2006 percent of watershed	2011 percent of watershed
Open Water	0	0	0
Developed - Open[1]	15	15	15
Developed - Low[1]	7	7	7
Developed - Medium[1]	0	0	0
Developed - High[1]	0	0	0
Barren	0	0	0
Deciduous	59	59	59
Evergreen	16	16	16
Mixed Forest	0	0	0
Shrub	3	3	3
Grassland	0	0	0
Pasture	0	0	0
Cultivated	0	0	0
Woody Wetland	0	0	0
Herbaceous Wetland	0	0	0

[1] refers to the intensity or type of development.

Table E-2. Geomorphic channel units (GCU) observed in the area between transects at CHAT009. The data describe the percent coverage of each type of GCU [SD—Standard deviation].

Transect	(%) Riffle	(%) Run	(%) Glide	(%) Pool	(%) Step
1–2	0	75	0	25	0
2–3	0	0	0	100	0
3–4	100	0	0	0	0
4–5	50	50	0	0	0
5–6	0	100	0	0	0
6–7	0	0	0	100	0
7–8	80	0	0	20	0

Table E-2 (continued). Geomorphic channel units (GCU) observed in the area between transects at CHAT009. The data describe the percent coverage of each type of GCU [SD—Standard deviation].

Transect	(%) Riffle	(%) Run	(%) Glide	(%) Pool	(%) Step
8–9	50	25	0	25	0
9–10	80	0	0	20	0
10–11	90	0	0	10	0
Frequency	6	4	0	7	0
Max (%)	100	100	0	100	0
Mean (%)	45	25	0	30	0
Median (%)	50	0	0	20	0
SD (%)	42	37	0	38	0

Table E-3. Characteristics of the large woody debris (LWD) observed at CHAT009 [m—meter].

LWD ID	Length (m)	Diameter (m)	Volume (m^3)	Transect Interval	Function	Position
1	2.42	0.21	0.08	9	Bank Protection, Organic trap	Buried
2	3.25	0.12	0.04	7	Organic trap, Sediment trap	Buried
3	1.17	0.12	0.01	7	Organic trap, Sediment trap	Buried

Table E-4. Variability of canopy cover observed at CHAT009 [SD—Standard deviation; CV—Coefficient of variation].

Transect	Canopy Cover (%)
1	94
2	96
3	93
4	94
5	96
6	94
7	94
8	94
9	100
10	97
11	99
Min (%)	93
Max (%)	100
Mean (%)	95
Median (%)	94
SD (%)	2
CV	0.02

Table E-5. Average reach-scale bank characteristics at CHAT009. [L indicates left bank and R indicates right bank; SD—Standard deviation; CV—Coefficient of variation; m—meters].

Bank Characteristics	n (L)	n (R)	Min (L)	Min (R)	Max (L)	Max (R)	Mean (L)	Mean (R)	Median (L)	Median (R)	SD (L)	SD (R)	CV (L)	CV (R)
Bank Height[1] (m)	11	11	0.64	0.72	1.12	1.02	0.95	0.88	1.01	0.88	0.16	0.12	0.17	0.13
Bankfull Height[1,2] (m)	0	0	0.00	0.00	0.00	0.00	–	–	–	–	–	–	–	–
Channel-full Height[1,2] (m)	11	11	0.67	0.80	1.19	1.05	1.00	0.93	1.05	0.94	0.17	0.10	0.17	0.11
Water Depth at Base[3] (m)	11	11	-0.11	-0.10	0.02	0.04	-0.04	-0.03	-0.03	-0.03	0.04	0.04	–	–
Bank Undercut[2] (m)	7	1	0.06	0.11	0.94	0.11	0.27	0.11	0.12	0.11	0.31	–	1.16	–
Bank Angle (°)	11	11	7	10	87	85	57	37	72	29	31	26	0.54	0.70
Vegetation Cover (%)	11	11	5	5	50	60	20	20	15	10	15	19	0.75	0.94
Bank Stability[4]	11	11	Unstable	Unstable	Very Unstable	Very Unstable	Unstable	Unstable	Unstable	Unstable	1.10	1.34	0.08	0.10

[1] above thalweg.

[2] statistics are based on the transects where feature is present (# in parentheses).

[3] a negative number indicates base of bank is above the water surface.

[4] see Table 1 for explanation of scores.

Table E-6. Cross-sectional characteristics for detailed transect 1 at CHAT009 [m—meter].

Type	Area (m^2)	Perimeter (m)	Hydraulic Radius (m)	Width (m)	Depth (m)	Width/Depth
Bankfull	0.85	3.32	0.26	2.97	0.50	5.94
Channel-full	3.19	6.55	0.49	5.97	1.03	5.77
Bankfull and Channel–full Ratio	3.75	1.97	1.90	2.01	2.07	0.97

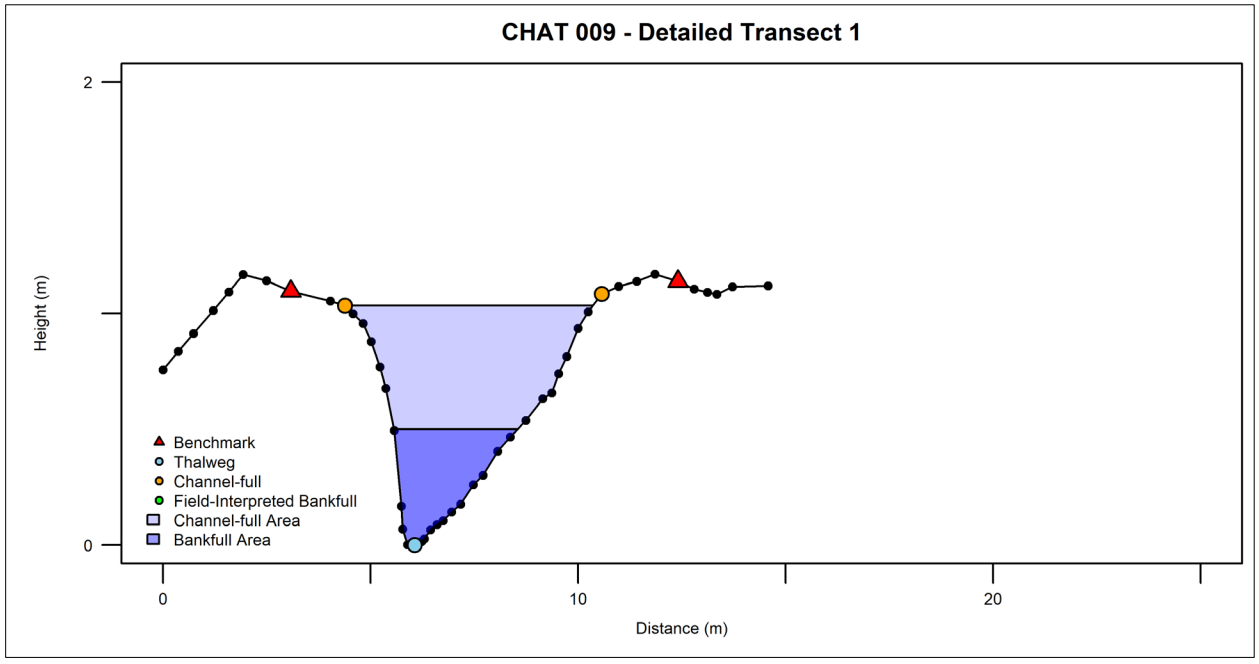


Figure E-14. Detailed transect 1 at CHAT009. The surveyed locations of the left and right benchmarks, channel-full bank-tops, and interpreted bankfull bank height are shown on the figure. Additionally, the channel-full (light blue) and bankfull (dark blue) cross-sectional areas are also included (channel-full cross-sectional area equals light blue plus dark blue).

Table E-7. Cross-sectional characteristics for detailed transect 2 at CHAT009 [m—meter].

Type	Area (m^2)	Perimeter (m)	Hydraulic Radius (m)	Width (m)	Depth (m)	Width/Depth
Bankfull	1.18	3.45	0.34	2.79	0.50	5.58
Channel-full	2.14	4.68	0.46	3.78	0.81	4.68
Bankfull and Channel–full Ratio	1.82	1.36	1.34	1.36	1.61	0.84

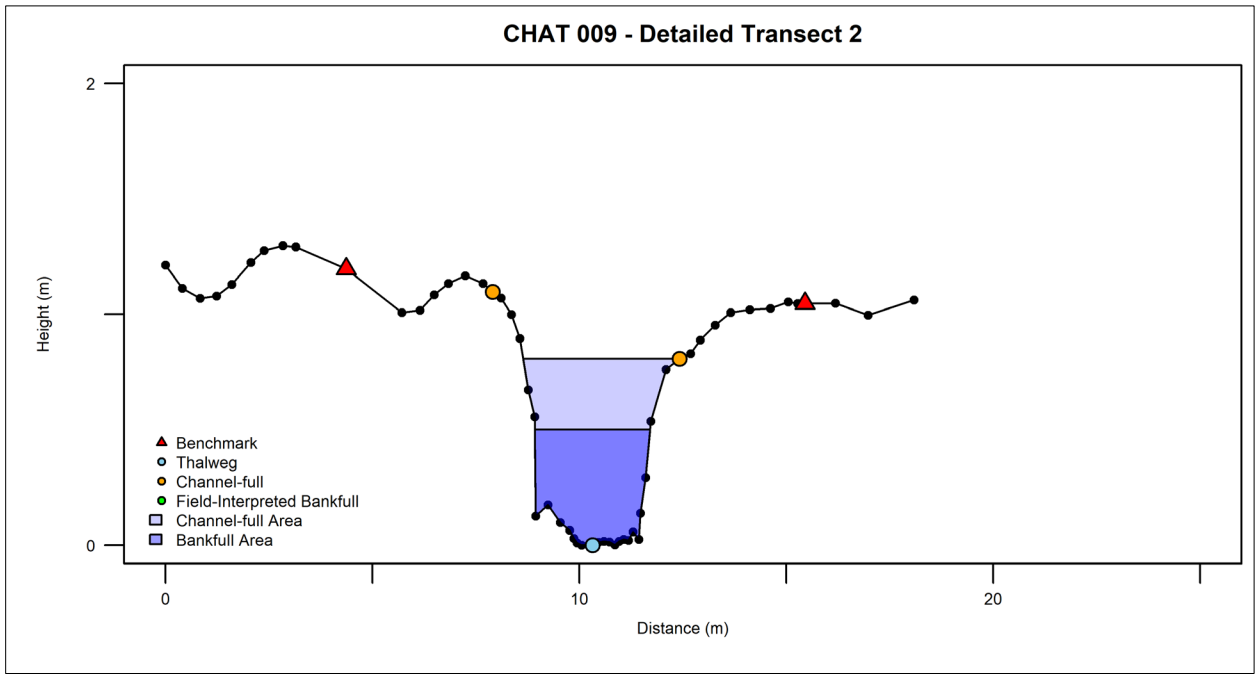


Figure E-15. Detailed transect 2 at CHAT009. The surveyed locations of the left and right benchmarks, channel-full bank-tops, and bankfull bank height are shown on the figure. Channel-full (light blue) and bankfull (dark blue) cross-sectional areas are also included (channel-full cross-sectional area equals light blue plus dark blue).

Table E-8. Cross-sectional characteristics for detailed transect 3 at CHAT009 [m—meter].

Type	Area (m^2)	Perimeter (m)	Hydraulic Radius (m)	Width (m)	Depth (m)	Width/Depth
Bankfull	1.12	3.69	0.30	3.23	0.50	6.46
Channel-full	1.58	4.31	0.37	3.72	0.63	5.89
Bankfull and Channel–full Ratio	1.40	1.17	1.20	1.15	1.26	0.91

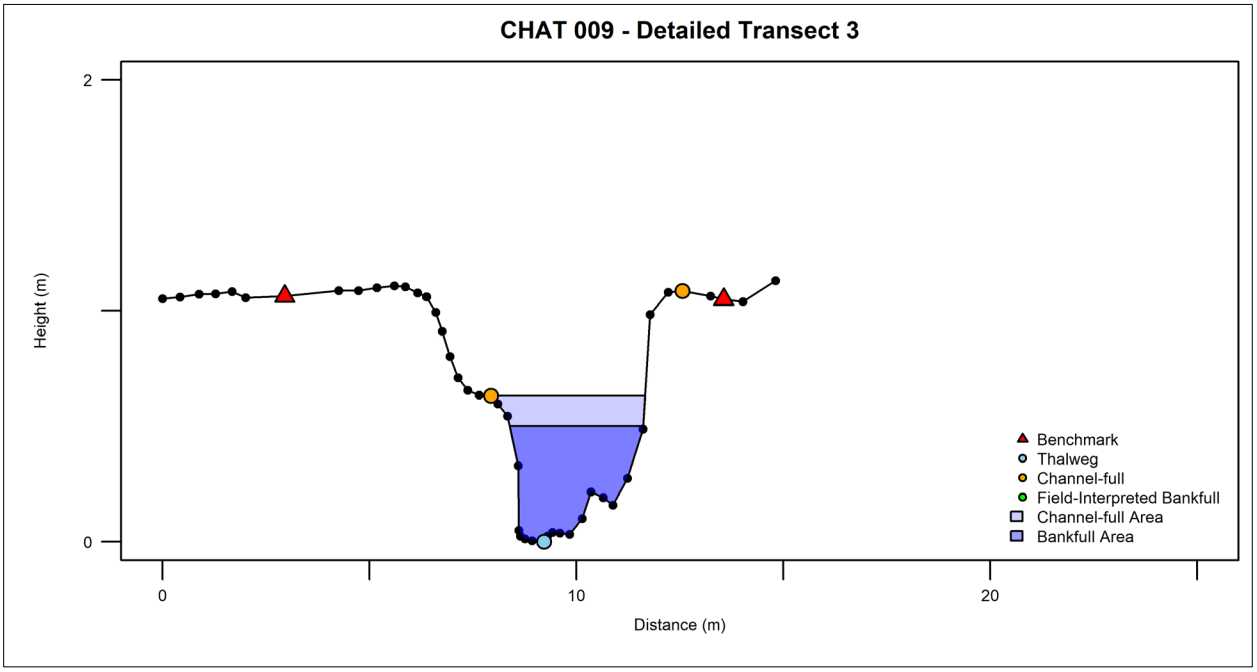


Figure E-16. Detailed transect 3 at CHAT009. The surveyed locations of the left and right benchmarks, channel-full bank-tops, and interpreted bankfull bank height are shown on the figure. Channel-full (light blue) and bankfull (dark blue) cross-sectional areas are also included (channel-full cross-sectional area equals light blue plus dark blue).

Literature Cited

Fry, J. A., G. Xian, S. Jin, J. A. Dewitz, C. G. Homer, L. Yang, C. A. Barnes, N. D. Herold, J. D. Wickham. 2006. Completion of the 2006 National Land Cover Database for the conterminous United States: Photogrammetric Engineering and Remote Sensing, v. 77, no. 9, p. 858–864.

Homer, C. G., J. A. Dewitz, J. A. Fry, M. J. Coan, S. M. Hossain, L. Nazmul, R. Charles, N. Herold, A. McKerrow, J. N Van Driel, J. Wickham. 2001. Completion of the 2001 National Land Cover Database for the conterminous United States: Photogrammetric Engineering and Remote Sensing, v. 73, no. 4, p. 337–341.

Homer, C. G., J. A. Dewitz, L. Yang, S. Jin, P. Danielson, G. Xian, J. Coulston, N. D. Herold, J. D. Wickham, and K. Megown. 2015. Completion of the 2011 national land cover database for the conterminous United States—representing a decade of land cover change information. Photogrammetric Engineering and Remote Sensing. 81:345–354.

United States Census Bureau (USCB). 2011. TIGER/Line Shapefiles-all roads, county-based. Available at https://www.census.gov/geographies/mapping-files/time-series/geo/tiger-line-file.2011.html (last accessed September 2019).

Appendix F. Survey Results for CHAT012

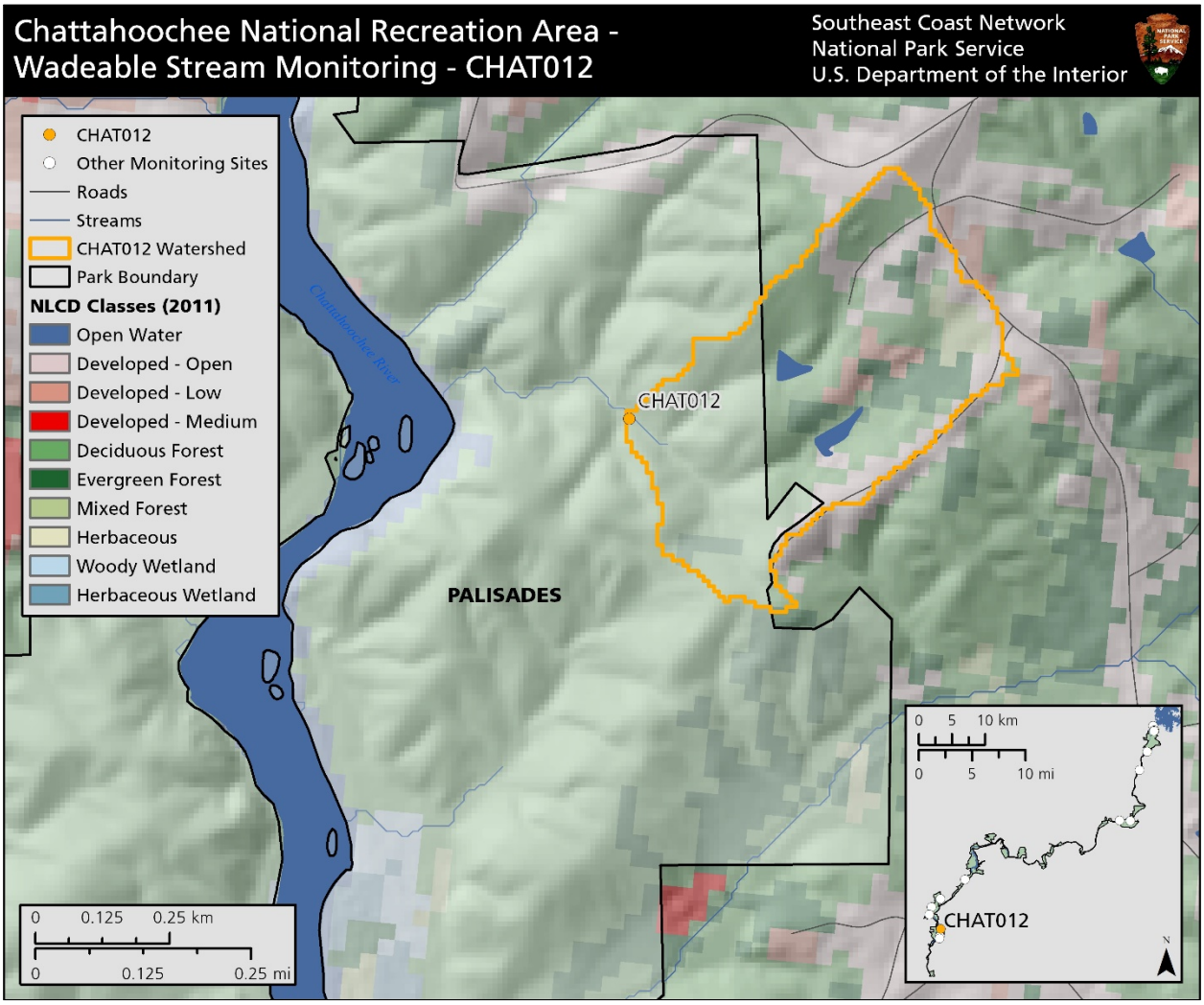


Figure F-1. Map showing the watershed draining to CHAT012 at Chattahoochee National Recreation Area. The land use/land cover (NLCD 2011, Homer et al. 2015), road network (USCB 2011), and perennial streams (derived from a 10-meter [32.8-feet] digital elevation model; data available from the U.S. Geological Survey) in the vicinity of the park are also shown.



Figure F-2. Photograph taken on CHAT012 looking upstream from T1 (detailed transect 1).



Figure F-3. Photograph taken on CHAT012 looking downstream from T1 (detailed transect 1).



Figure F-4. Photograph taken on CHAT012 looking at the left bank from T1 (detailed transect 1).



Figure F-5. Photograph taken on CHAT012 looking at the right bank from T1 (detailed transect 1).



Figure F-6. Photograph taken on CHAT012 looking upstream from T6 (detailed transect 2).



Figure F-7. Photograph taken on CHAT012 looking downstream from T6 (detailed transect 2).



Figure F-8. Photograph taken on CHAT012 looking at the left bank from T6 (detailed transect 2).



Figure F-9. Photograph taken on CHAT012 looking at the right bank from T6 (detailed transect 2).



Figure F-10. Photograph taken on CHAT012 looking upstream from T9 (detailed transect 3).



Figure F-11. Photograph taken on CHAT012 looking downstream from T9 (detailed transect 3).



Figure F-12. Photograph taken on CHAT012 looking at the left bank from T9 (detailed transect 3).



Figure F-13. Photograph taken on CHAT012 looking at the right bank from T9 (detailed transect 3).

Table F-1. Land use/land cover characteristics for 2001, 2006, and 2011 for CHAT012. The data included in this table are from the National Land Cover Dataset (Fry et al. 2001; Homer et al. 2006; Homer et al. 2015).

NLCD Class	2001 percent of watershed	2006 percent of watershed	2011 percent of watershed
Open Water	0	0	0
Developed - Open[1]	19	19	19
Developed - Low[1]	4	4	4
Developed - Medium[1]	0	0	0
Developed - High[1]	0	0	0
Barren	0	0	0
Deciduous	64	64	64
Evergreen	10	10	10
Mixed Forest	3	3	3
Shrub	0	0	0
Grassland	0	0	0
Pasture	0	0	0
Cultivated	0	0	0
Woody Wetland	0	0	0
Herbaceous Wetland	0	0	0

[1] refers to the intensity or type of development.

Table F-2. Geomorphic channel units (GCU) observed in the area between transects at CHAT012. The data describe the percent coverage of each type of GCU [SD—Standard deviation].

Transect	(%) Riffle	(%) Run	(%) Glide	(%) Pool	(%) Step
1–2	0	0	0	100	0
2–3	100	0	0	0	0
3–4	0	0	0	50	50
4–5	0	50	0	50	0
5–6	0	0	0	100	0
6–7	50	50	0	0	0

Table F-2 (continued). Geomorphic channel units (GCU) observed in the area between transects at CHAT012. The data describe the percent coverage of each type of GCU [SD—Standard deviation].

Transect	(%) Riffle	(%) Run	(%) Glide	(%) Pool	(%) Step
7–8	100	0	0	0	0
8–9	50	50	0	0	0
9–10	100	0	0	0	0
10–11	100	0	0	0	0
Frequency	6	3	0	4	1
Max (%)	100	50	0	100	50
Mean (%)	50	15	0	30	5
Median (%)	50	0	0	0	0
SD (%)	47	24	0	42	16

Table F-3. Characteristics of the large woody debris (LWD) observed at CHAT012 [m—meter].

LWD ID	Length (m)	Diameter (m)	Volume (m^3)	Transect Interval	Function	Position
1	1.10	0.10	0.01	2	None	Free
2	2.00	0.19	0.06	1	Organic trap	Free

Table F4. Variability of canopy cover observed at CHAT012 [SD—Standard deviation; CV—Coefficient of variation].

Transect	Canopy Cover (%)
1	94
2	99
3	93
4	91
5	85
6	97
7	94
8	96
9	97
10	93
11	99
Min (%)	85
Max (%)	99
Mean (%)	94
Median (%)	94
SD (%)	4
CV	0.04

Table F-5. Average reach-scale bank characteristics at CHAT012. [L indicates left bank and R indicates right bank; SD—Standard deviation; CV—Coefficient of variation; m—meters].

Bank Characteristics	n (L)	n (R)	Min (L)	Min (R)	Max (L)	Max (R)	Mean (L)	Mean (R)	Median (L)	Median (R)	SD (L)	SD (R)	CV (L)	CV (R)
Bank Height[1] (m)	11	11	0.28	0.59	0.66	0.73	0.51	0.64	0.51	0.62	0.11	0.04	0.22	0.07
Bankfull Height[1,2] (m)	3	4	0.25	0.37	0.32	0.47	0.28	0.44	0.28	0.45	0.04	0.04	0.12	0.10
Channel-full Height[1,2] (m)	11	11	0.33	0.63	0.70	0.82	0.56	0.69	0.58	0.66	0.11	0.07	0.19	0.10
Water Depth at Base[3] (m)	11	11	-0.05	-0.08	0.02	0.02	-0.02	-0.01	-0.01	0.00	0.02	0.03	–	–
Bank Undercut[2] (m)	2	5	0.12	0.11	0.37	0.38	0.25	0.23	0.25	0.21	0.18	0.10	0.72	0.43
Bank Angle (°)	11	11	17	15	88	89	56	57	59	63	25	30	0.45	0.53
Vegetation Cover (%)	11	11	0	5	90	70	29	34	30	30	30	27	1.04	0.80
Bank Stability[4]	11	11	Unstable	Unstable	Unstable	Unstable	Unstable	Unstable	Unstable	Unstable	1.08	1.21	0.08	0.09

[1] above thalweg.

[2] statistics are based on the transects where feature is present (# in parentheses).

[3] a negative number indicates base of bank is above the water surface.

[4] see Table 1 for explanation of scores.

Table F-6. Cross-sectional characteristics for detailed transect 1 at CHAT012 [m—meter].

Type	Area (m^2)	Perimeter (m)	Hydraulic Radius (m)	Width (m)	Depth (m)	Width/Depth
Bankfull	0.62	2.96	0.21	2.73	0.27	9.94
Channel-full	1.47	4.47	0.33	4.14	0.53	7.84
Bankfull and Channel–full Ratio	2.36	1.51	1.56	1.52	1.93	0.79

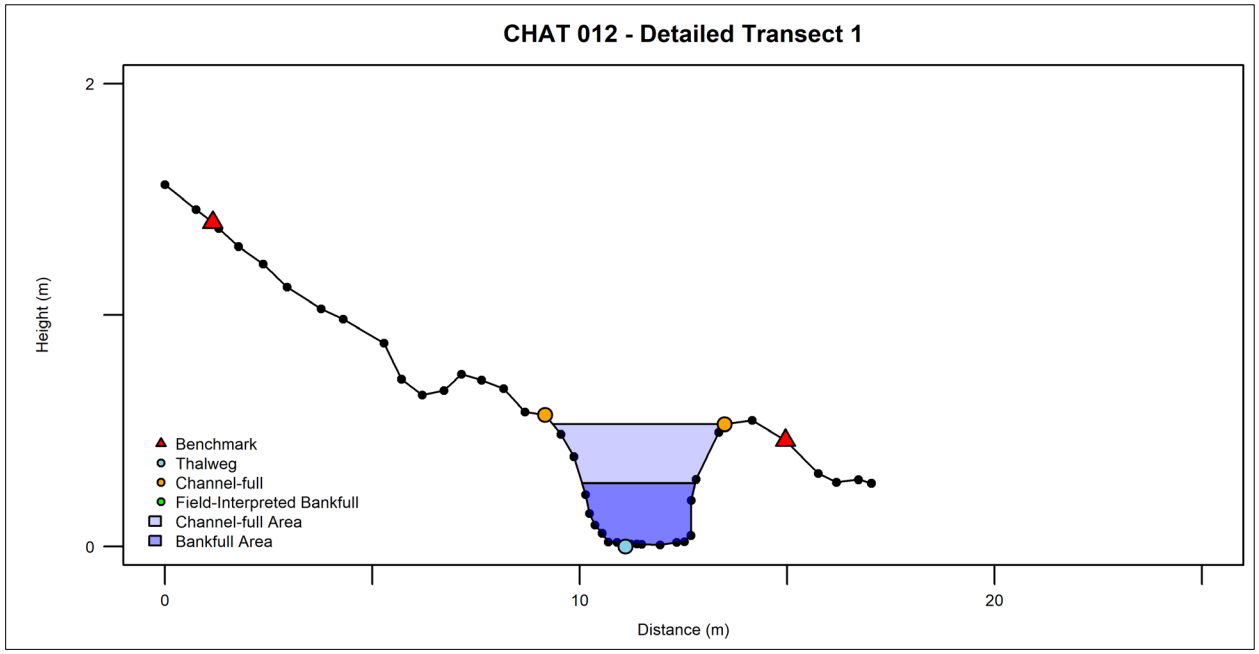


Figure F-14. Detailed transect 1 at CHAT012. The surveyed locations of the left and right benchmarks, channel-full bank-tops, and interpreted bankfull bank height are shown on the figure. Additionally, the channel-full (light blue) and bankfull (dark blue) cross-sectional areas are also included (channel-full cross-sectional area equals light blue plus dark blue).

Table F-7. Cross-sectional characteristics for detailed transect 2 at CHAT012 [m—meter].

Type	Area (m^2)	Perimeter (m)	Hydraulic Radius (m)	Width (m)	Depth (m)	Width/Depth
Bankfull	0.56	2.62	0.21	2.23	0.47	4.70
Channel-full	0.69	3.42	0.20	3.02	0.52	5.75
Bankfull and Channel–full Ratio	1.23	1.30	0.94	1.35	1.10	1.22

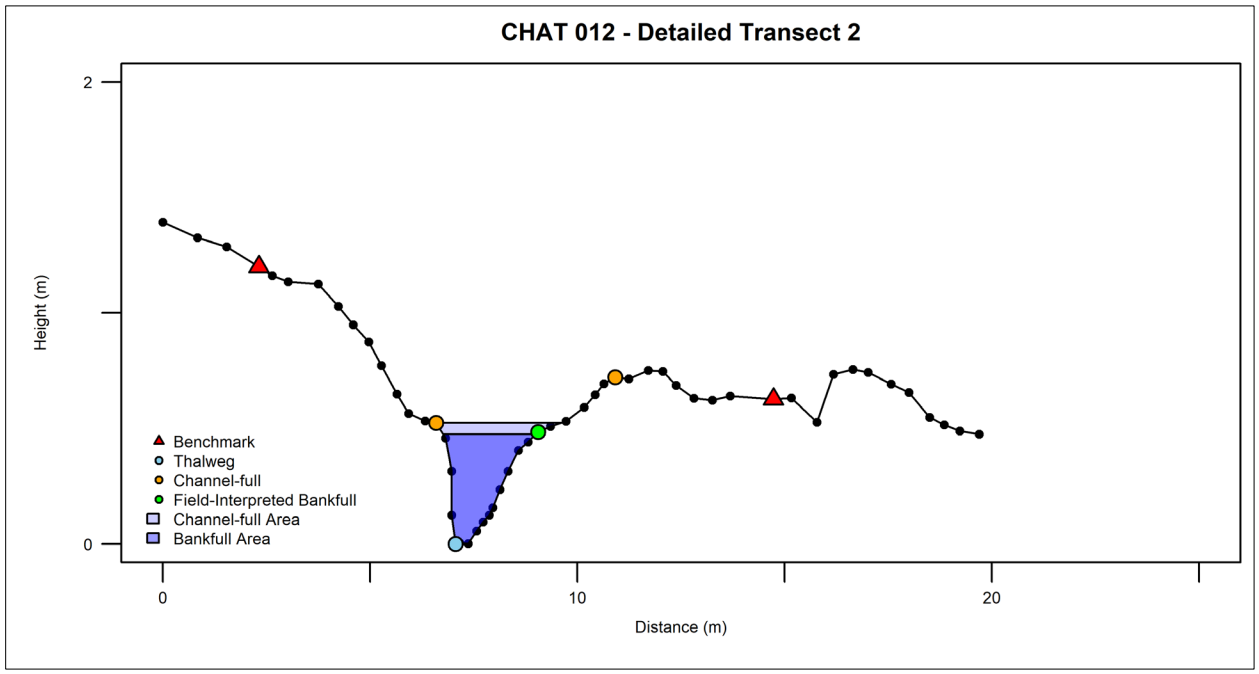


Figure F-15. Detailed transect 2 at CHAT012. The surveyed locations of the left and right benchmarks, channel-full bank-tops, and bankfull bank height are shown on the figure. Channel-full (light blue) and bankfull (dark blue) cross-sectional areas are also included (channel-full cross-sectional area equals light blue plus dark blue).

Table F-8. Cross-sectional characteristics for detailed transect 3 at CHAT012 [m—meter].

Type	Area (m^2)	Perimeter (m)	Hydraulic Radius (m)	Width (m)	Depth (m)	Width/Depth
Bankfull	0.24	1.70	0.14	1.48	0.21	7.06
Channel-full	0.87	3.35	0.26	2.93	0.49	6.00
Bankfull and Channel–full Ratio	3.71	1.97	1.89	1.98	2.33	0.85

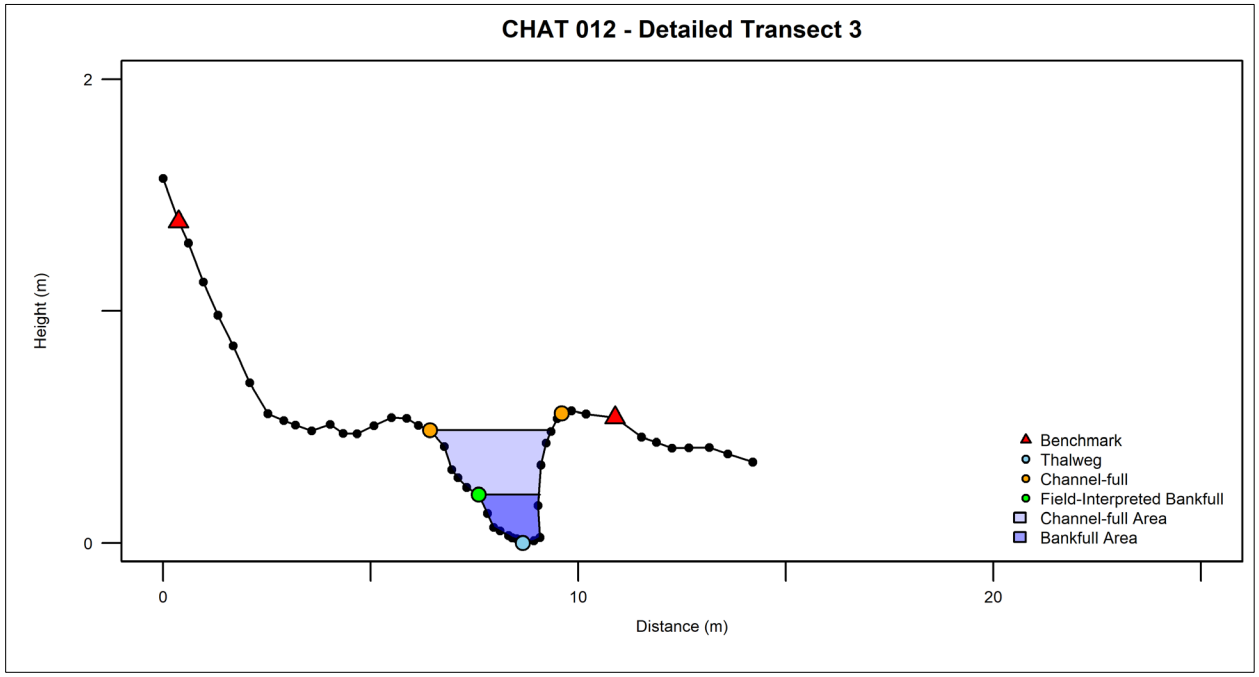


Figure F-16. Detailed transect 3 at CHAT012. The surveyed locations of the left and right benchmarks, channel-full bank-tops, and interpreted bankfull bank height are shown on the figure. Channel-full (light blue) and bankfull (dark blue) cross-sectional areas are also included (channel-full cross-sectional area equals light blue plus dark blue).

Literature Cited

Fry, J. A., G. Xian, S. Jin, J. A. Dewitz, C. G. Homer, L. Yang, C. A. Barnes, N. D. Herold, J. D. Wickham. 2006. Completion of the 2006 National Land Cover Database for the conterminous United States: Photogrammetric Engineering and Remote Sensing, v. 77, no. 9, p. 858–864.

Homer, C. G., J. A. Dewitz, J. A. Fry, M. J. Coan, S. M. Hossain, L. Nazmul, R. Charles, N. Herold, A. McKerrow, J. N Van Driel, J. Wickham. 2001. Completion of the 2001 National Land Cover Database for the conterminous United States: Photogrammetric Engineering and Remote Sensing, v. 73, no. 4, p. 337–341.

Homer, C. G., J. A. Dewitz, L. Yang, S. Jin, P. Danielson, G. Xian, J. Coulston, N. D. Herold, J. D. Wickham, and K. Megown. 2015. Completion of the 2011 national land cover database for the conterminous United States—representing a decade of land cover change information. Photogrammetric Engineering and Remote Sensing. 81:345–354.

United States Census Bureau (USCB). 2011. TIGER/Line Shapefiles-all roads, county-based. Available at https://www.census.gov/geographies/mapping-files/time-series/geo/tiger-line-file.2011.html (last accessed September 2019).

Appendix G. Survey Results for CHAT004

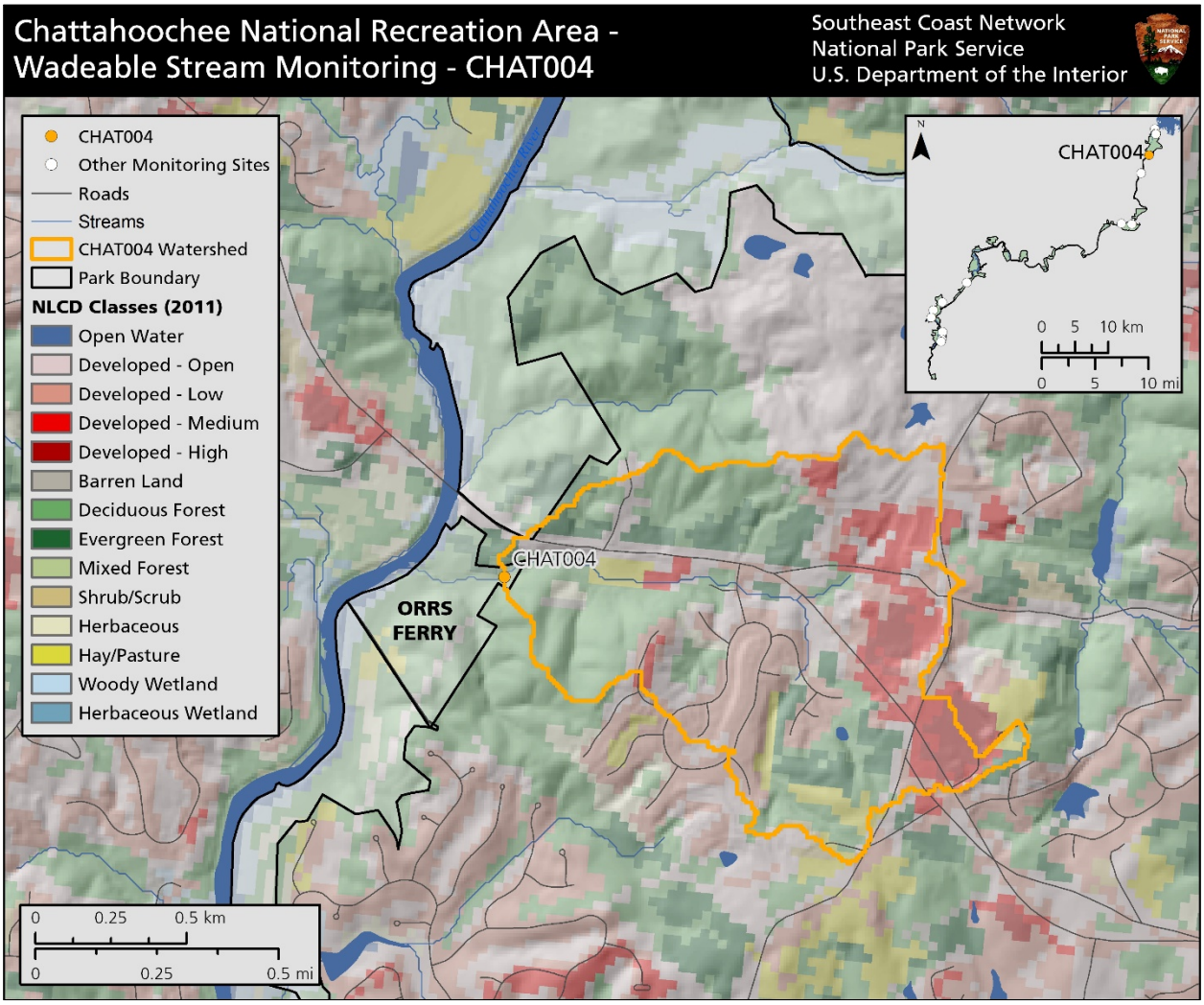


Figure G-1. Map showing the watershed draining to CHAT004 at Chattahoochee National Recreation Area. The land use/land cover (NLCD 2011, Homer et al. 2015), road network (USCB 2011), and perennial streams (derived from a 10-meter [32.8-feet] digital elevation model; data available from the U.S. Geological Survey) in the vicinity of the park are also shown.



Figure G-2. Photograph taken on CHAT004 looking upstream from T1 (detailed transect 1).



Figure G-3. Photograph taken on CHAT004 looking downstream from T1 (detailed transect 1).



Figure G-4. Photograph taken on CHAT004 looking at the left bank from T1 (detailed transect 1).



Figure G-5. Photograph taken on CHAT004 looking at the right bank from T1 (detailed transect 1).



Figure G-6. Photograph taken on CHAT004 looking upstream from T5 (detailed transect 2).



Figure G-7. Photograph taken on CHAT004 looking downstream from T5 (detailed transect 2).



Figure G-8. Photograph taken on CHAT004 looking at the left bank from T5 (detailed transect 2).



Figure G-9. Photograph taken on CHAT004 looking at the right bank from T5 (detailed transect 2).

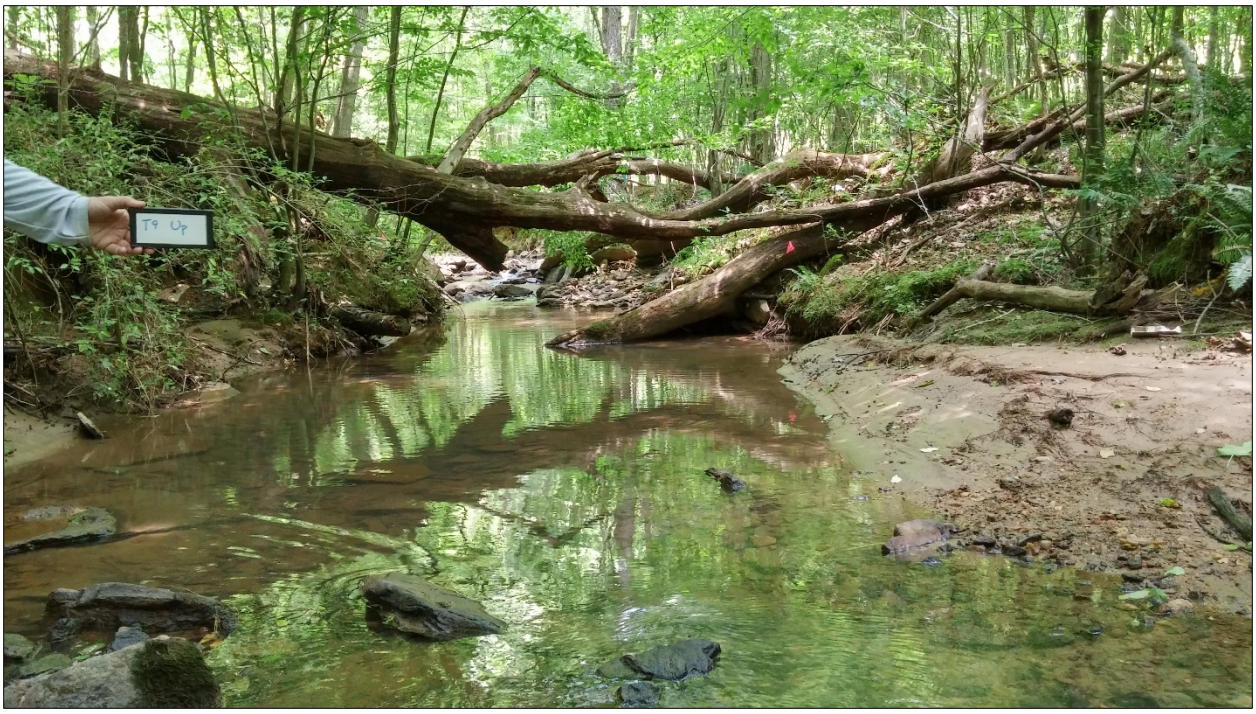


Figure G-10. Photograph taken on CHAT004 looking upstream from T9 (detailed transect 3).



Figure G-11. Photograph taken on CHAT004 looking downstream from T9 (detailed transect 3).



Figure G-12. Photograph taken on CHAT004 looking at the left bank from T9 (detailed transect 3).



Figure G-13. Photograph taken on CHAT004 looking at the right bank from T9 (detailed transect 3).

Table G-1. Land use/land cover characteristics for 2001, 2006, and 2011 for CHAT004. The data included in this table are from the National Land Cover Dataset (Fry et al. 2001; Homer et al. 2006; Homer et al. 2015).

NLCD Class	2001 percent of watershed	2006 percent of watershed	2011 percent of watershed
Open Water	0	0	0
Developed - Open[1]	20	22	21
Developed - Low[1]	17	19	20
Developed - Medium[1]	4	7	11
Developed - High[1]	2	2	4
Barren	1	1	0
Deciduous	34	31	28
Evergreen	14	12	10
Mixed Forest	0	0	0
Shrub	0	0	0
Grassland	3	1	1
Pasture	6	5	4
Cultivated	0	0	0
Woody Wetland	0	0	0
Herbaceous Wetland	0	0	0

[1] refers to the intensity or type of development.

Table G-2. Geomorphic channel units (GCU) observed in the area between transects at CHAT004. The data describe the percent coverage of each type of GCU [SD—Standard deviation].

Transect	(%) Riffle	(%) Run	(%) Glide	(%) Pool	(%) Step
1–2	95	0	0	5	0
2–3	50	30	0	20	0
3–4	15	0	0	85	0
4–5	15	70	0	15	0
5–6	75	0	0	25	0
6–7	0	25	0	75	0
7–8	90	10	0	0	0

Table G-2 (continued). Geomorphic channel units (GCU) observed in the area between transects at CHAT004. The data describe the percent coverage of each type of GCU [SD—Standard deviation].

Transect	(%) Riffle	(%) Run	(%) Glide	(%) Pool	(%) Step
8–9	20	80	0	0	0
9–10	0	0	0	100	0
10–11	25	50	0	25	0
Frequency	8	6	0	8	0
Max (%)	95	80	0	100	0
Mean (%)	39	27	0	35	0
Median (%)	23	18	0	23	0
SD (%)	36	31	0	37	0

Table G-3. Characteristics of the large woody debris (LWD) observed at CHAT004 [m—meter].

LWD ID	Length (m)	Diameter (m)	Volume (m^3)	Transect Interval	Function	Position
1	6.63	0.22	0.25	11	None	Bridge
2	5.70	0.60	1.61	10	None	Bridge
3	2.22	0.13	0.03	10	Bank Protection	Buried
4	2.03	0.21	0.07	10	Organic trap	Ramp
5	2.50	0.12	0.03	10	None	Free
6	2.01	0.25	0.10	8	Sediment trap	Buried
7	2.90	0.10	0.02	4	None	Jam
8	2.00	0.13	0.03	4	Jam, Organic trap	Jam
9	6.34	0.40	0.80	4	Jam	Bridge
10	3.40	0.10	0.03	2	Jam, Bank Protection, Organic trap	Jam

Table G-4. Variability of canopy cover observed at CHAT004 [SD—Standard deviation; CV—Coefficient of variation].

Transect	Canopy Cover (%)
1	88
2	97
3	88
4	99
5	93
6	90
7	94
8	94
9	97
10	99
11	91
Min (%)	88
Max (%)	99
Mean (%)	94
Median (%)	94
SD (%)	4
CV	0.04

Table G-5. Average reach-scale bank characteristics at CHAT004. [L indicates left bank and R indicates right bank; SD—Standard deviation; CV—Coefficient of variation; m—meters].

Bank Characteristics	n (L)	n (R)	Min (L)	Min (R)	Max (L)	Max (R)	Mean (L)	Mean (R)	Median (L)	Median (R)	SD (L)	SD (R)	CV (L)	CV (R)
Bank Height[1] (m)	11	11	0.79	0.72	2.06	1.95	1.52	1.49	1.72	1.69	0.49	0.45	0.32	0.30
Bankfull Height[1,2] (m)	0	0	0.00	0.00	0.00	0.00	–	–	–	–	–	–	–	–
Channel-full Height[1,2] (m)	11	11	0.89	0.84	2.23	2.12	1.68	1.65	1.95	1.82	0.49	0.43	0.29	0.26
Water Depth at Base[3] (m)	11	11	-0.12	-0.16	0.16	0.10	0.00	-0.02	0.00	0.00	0.07	0.09	–	–
Bank Undercut[2] (m)	5	8	0.16	0.11	0.41	0.32	0.23	0.19	0.20	0.14	0.10	0.08	0.45	0.45
Bank Angle (°)	11	11	34	38	92	89	66	69	66	72	15	16	0.23	0.23
Vegetation Cover (%)	11	11	0	10	95	95	40	40	30	40	29	24	0.74	0.61
Bank Stability[4]	11	11	Unstable	Unstable	Very Unstable	Very Unstable	Unstable	Unstable	Unstable	Unstable	1.96	1.36	0.15	0.10

[1] above thalweg.

[2] statistics are based on the transects where feature is present (# in parentheses).

[3] a negative number indicates base of bank is above the water surface.

[4] see Table 1 for explanation of scores.

Table G-6. Cross-sectional characteristics for detailed transect 1 at CHAT004 [m—meter].

Type	Area (m^2)	Perimeter (m)	Hydraulic Radius (m)	Width (m)	Depth (m)	Width/Depth
Bankfull	1.55	4.43	0.35	3.93	0.56	7.02
Channel-full	3.43	6.22	0.55	5.47	0.97	5.64
Bankfull and Channel–full Ratio	2.22	1.40	1.58	1.39	1.73	0.80

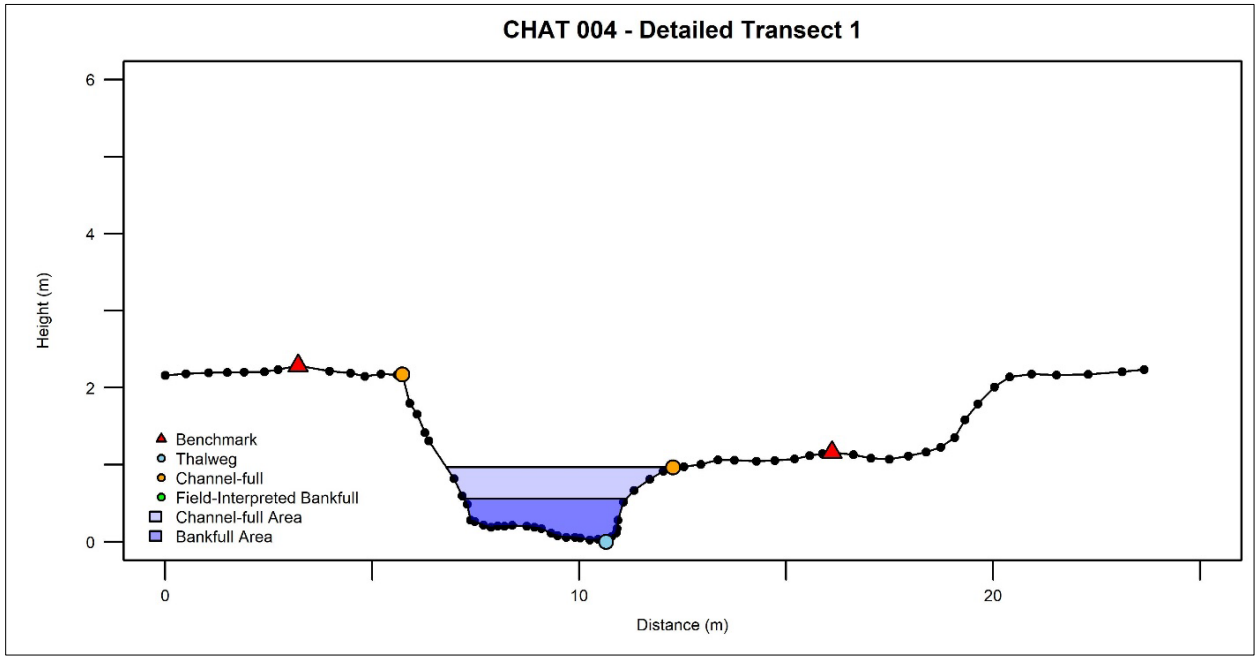


Figure G-14. Detailed transect 1 at CHAT004. The surveyed locations of the left and right benchmarks, channel-full bank-tops, and interpreted bankfull bank height are shown on the figure. Additionally, the channel-full (light blue) and bankfull (dark blue) cross-sectional areas are also included (channel-full cross-sectional area equals light blue plus dark blue).

Table G-7. Cross-sectional characteristics for detailed transect 2 at CHAT004 [m—meter].

Type	Area (m^2)	Perimeter (m)	Hydraulic Radius (m)	Width (m)	Depth (m)	Width/Depth
Bankfull	2.14	5.37	0.40	4.90	0.56	8.75
Channel-full	10.73	10.10	1.06	8.63	1.88	4.60
Bankfull and Channel–full Ratio	5.01	1.88	2.66	1.76	3.35	0.53

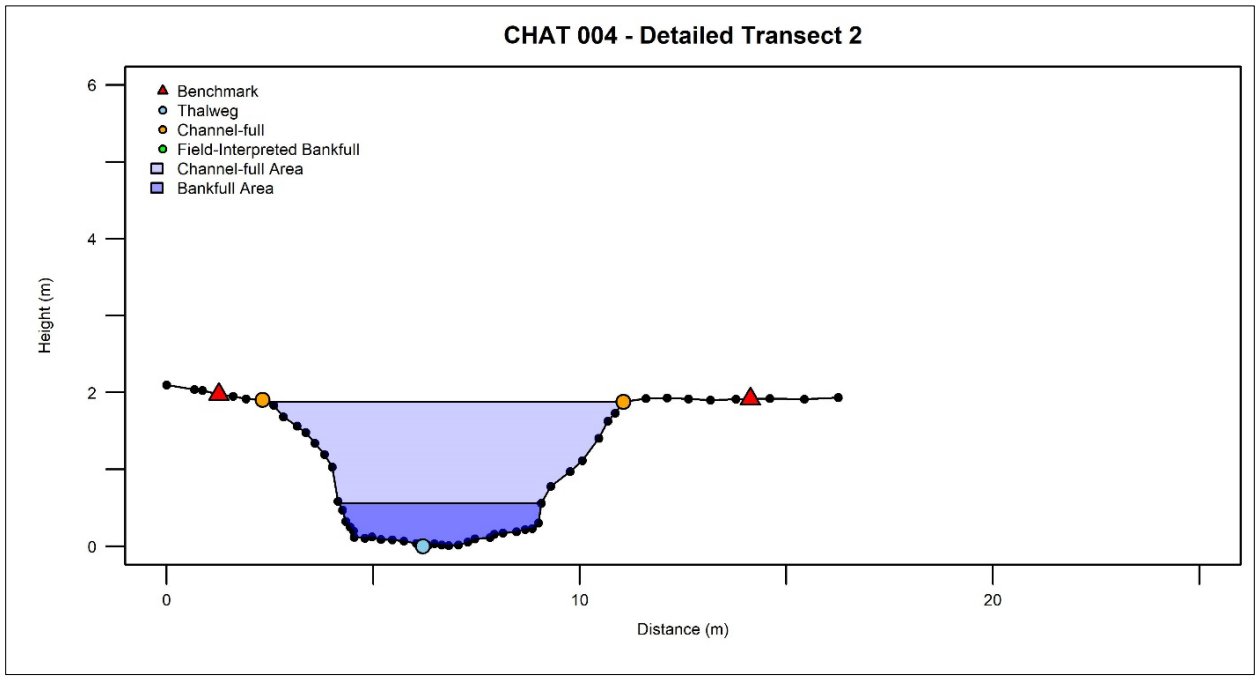


Figure G-15. Detailed transect 2 at CHAT004. The surveyed locations of the left and right benchmarks, channel-full bank-tops, and bankfull bank height are shown on the figure. Channel-full (light blue) and bankfull (dark blue) cross-sectional areas are also included (channel-full cross-sectional area equals light blue plus dark blue).

Table G-8. Cross-sectional characteristics for detailed transect 3 at CHAT004 [m—meter].

Type	Area (m^2)	Perimeter (m)	Hydraulic Radius (m)	Width (m)	Depth (m)	Width/Depth
Bankfull	2.00	5.00	0.40	4.49	0.56	8.02
Channel-full	7.95	8.48	0.94	7.05	1.62	4.36
Bankfull and Channel–full Ratio	3.98	1.70	2.35	1.57	2.89	0.54

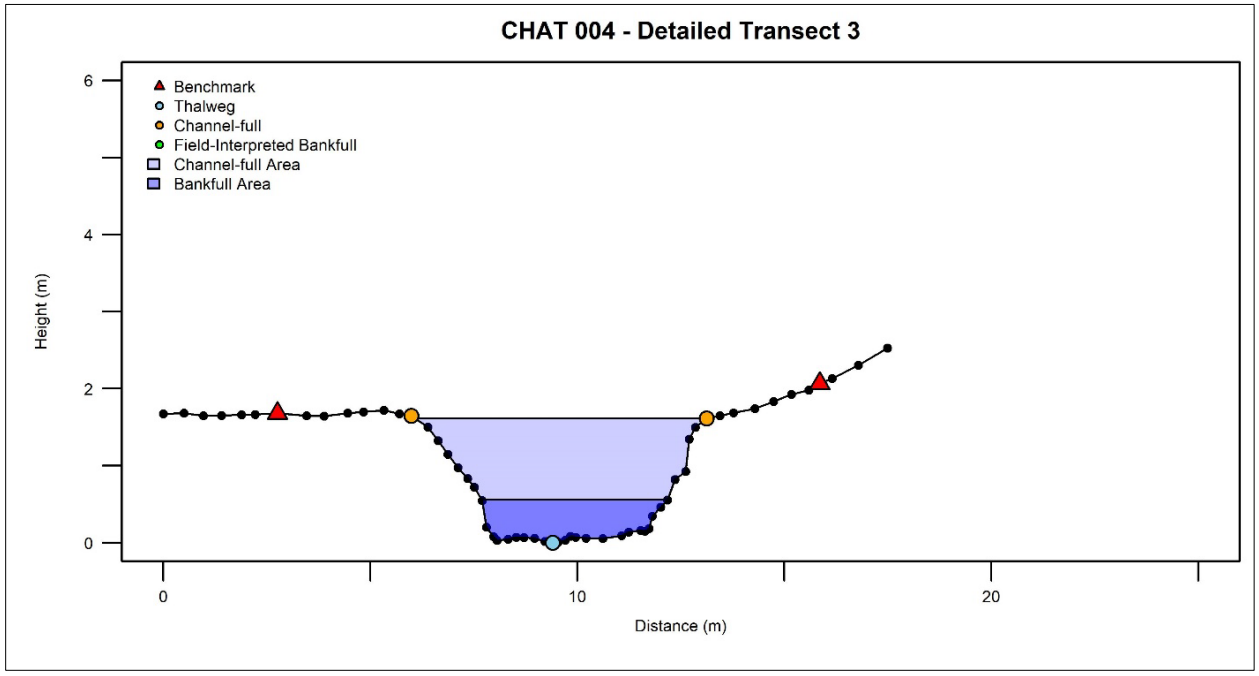


Figure G-16. Detailed transect 3 at CHAT004. The surveyed locations of the left and right benchmarks, channel-full bank-tops, and interpreted bankfull bank height are shown on the figure. Channel-full (light blue) and bankfull (dark blue) cross-sectional areas are also included (channel-full cross-sectional area equals light blue plus dark blue).

Literature Cited

Fry, J. A., G. Xian, S. Jin, J. A. Dewitz, C. G. Homer, L. Yang, C. A. Barnes, N. D. Herold, J. D. Wickham. 2006. Completion of the 2006 National Land Cover Database for the conterminous United States: Photogrammetric Engineering and Remote Sensing, v. 77, no. 9, p. 858–864.

Homer, C. G., J. A. Dewitz, J. A. Fry, M. J. Coan, S. M. Hossain, L. Nazmul, R. Charles, N. Herold, A. McKerrow, J. N Van Driel, J. Wickham. 2001. Completion of the 2001 National Land Cover Database for the conterminous United States: Photogrammetric Engineering and Remote Sensing, v. 73, no. 4, p. 337–341.

Homer, C. G., J. A. Dewitz, L. Yang, S. Jin, P. Danielson, G. Xian, J. Coulston, N. D. Herold, J. D. Wickham, and K. Megown. 2015. Completion of the 2011 national land cover database for the conterminous United States—representing a decade of land cover change information. Photogrammetric Engineering and Remote Sensing. 81:345–354.

United States Census Bureau (USCB). 2011. TIGER/Line Shapefiles-all roads, county-based. Available at https://www.census.gov/geographies/mapping-files/time-series/geo/tiger-line-file.2011.html (last accessed September 2019).

Appendix H. Survey Results for CHAT005

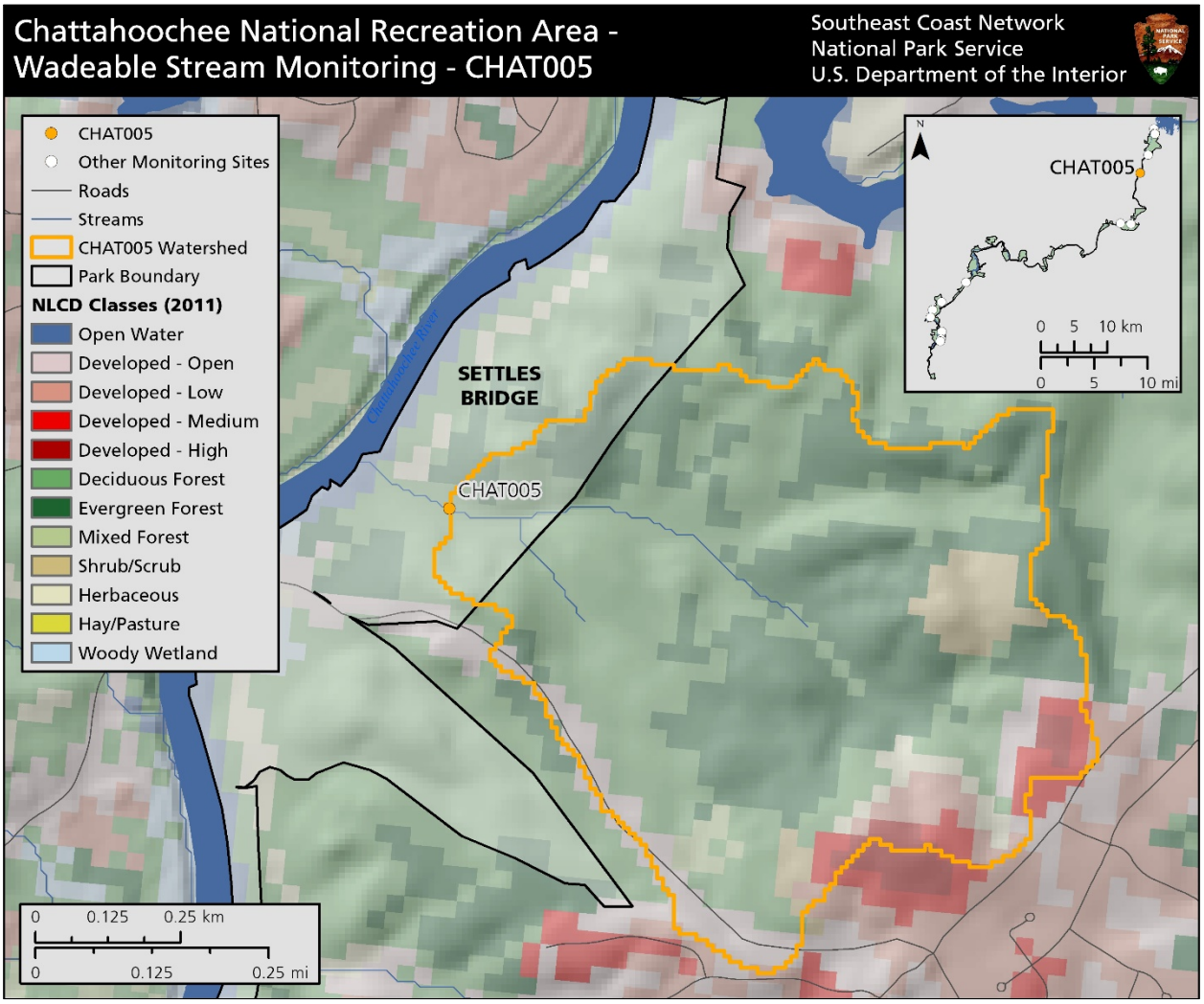


Figure H-1. Map showing the watershed draining to CHAT005 at Chattahoochee National Recreation Area. The land use/land cover (NLCD 2011, Homer et al. 2015), road network (USCB 2011), and perennial streams (derived from a 10-meter [32.8-feet] digital elevation model; data available from the U.S. Geological Survey) in the vicinity of the park are also shown.



Figure H-2. Photograph taken on CHAT005 looking upstream from T1 (detailed transect 1).



Figure H-3. Photograph taken on CHAT005 looking downstream from T1 (detailed transect 1).



Figure H-4. Photograph taken on CHAT005 looking at the left bank from T1 (detailed transect 1).



Figure H-5. Photograph taken on CHAT005 looking at the right bank from T1 (detailed transect 1).



Figure H-6. Photograph taken on CHAT005 looking upstream from T6 (detailed transect 2).



Figure H-7. Photograph taken on CHAT005 looking downstream from T6 (detailed transect 2).



Figure H-8. Photograph taken on CHAT005 looking at the left bank from T6 (detailed transect 2).



Figure H-9. Photograph taken on CHAT005 looking at the right bank from T6 (detailed transect 2).



Figure H-10. Photograph taken on CHAT005 looking upstream from T11 (detailed transect 3).



Figure H-11. Photograph taken on CHAT005 looking downstream from T11 (detailed transect 3).



Figure H-12. Photograph taken on CHAT005 looking at the left bank from T11 (detailed transect 3).



Figure H-13. Photograph taken on CHAT005 looking at the right bank from T11 (detailed transect 3).

Table H-1. Land use/land cover characteristics for 2001, 2006, and 2011 for CHAT005. The data included in this table are from the National Land Cover Dataset (Fry et al. 2001; Homer et al. 2006; Homer et al. 2015).

NLCD Class	2001 percent of watershed	2006 percent of watershed	2011 percent of watershed
Open Water	0	0	0
Developed - Open[1]	4	4	5
Developed - Low[1]	3	3	3
Developed - Medium[1]	1	1	2
Developed - High[1]	1	1	1
Barren	0	0	0
Deciduous	44	44	43
Evergreen	44	44	38
Mixed Forest	1	1	1
Shrub	1	1	4
Grassland	2	2	2
Pasture	0	0	0
Cultivated	0	0	0
Woody Wetland	0	0	0
Herbaceous Wetland	0	0	0

[1] refers to the intensity or type of development.

Table H-2. Geomorphic channel units (GCU) observed in the area between transects at CHAT005. The data describe the percent coverage of each type of GCU. [SD—Standard deviation].

Transect	(%) Riffle	(%) Run	(%) Glide	(%) Pool	(%) Step
1–2	0	0	0	100	0
2–3	0	0	0	100	0
3–4	60	0	0	20	20
4–5	80	0	0	20	0
5–6	40	10	0	50	0
6–7	75	0	0	25	0
7–8	65	15	0	20	0

Table H-2 (continued). Geomorphic channel units (GCU) observed in the area between transects at CHAT005. The data describe the percent coverage of each type of GCU. [SD—Standard deviation].

Transect	(%) Riffle	(%) Run	(%) Glide	(%) Pool	(%) Step
8–9	30	0	0	70	0
9–10	60	40	0	0	0
10–11	25	75	0	0	0
Frequency	8	4	0	8	1
Max (%)	80	75	0	100	20
Mean (%)	44	14	0	41	2
Median (%)	50	0	0	23	0
SD (%)	29	25	0	38	6

Table H-3. Characteristics of the large woody debris (LWD) observed at CHAT005 [m—meter].

LWD ID	Length (m)	Diameter (m)	Volume (m^3)	Transect Interval	Function	Position
1	3.01	0.12	0.03	11	None	Free
2	1.76	0.10	0.01	10	Organic trap, Sediment trap	Buried
3	2.04	0.24	0.09	9	Organic trap, Sediment trap, Bank Protection	Buried
4	1.66	0.14	0.03	8	Organic trap, Sediment trap	Buried
5	3.00	0.22	0.11	4	Pool formation, Sediment trap, Organic trap, Bank Protection	Buried
6	3.59	0.09	0.02	3	Jam, Organic trap, Sediment trap	Jam
7	2.53	0.16	0.05	3	Jam, Organic trap, Sediment trap	Jam
8	1.02	0.10	0.01	2	Jam, Organic trap, Sediment trap	Jam
9	2.14	0.12	0.02	2	Jam	Jam
10	4.18	0.26	0.22	2	Jam	Jam
11	1.10	0.21	0.04	2	Jam	Jam

Table H-4. Variability of canopy cover observed at CHAT005 [SD—Standard deviation].

Transect	Canopy Cover (%)
1	94
2	97
3	91
4	93
5	94
6	91
7	88
8	88
9	87
10	90
11	85
Min (%)	85
Max (%)	97
Mean (%)	91
Median (%)	91
SD (%)	4
CV	0.04

Table H-5. Average reach-scale bank characteristics at CHAT005. [L indicates left bank and R indicates right bank; SD—Standard deviation; CV—Coefficient of variation; m—meters].

Bank Characteristics	n (L)	n (R)	Min (L)	Min (R)	Max (L)	Max (R)	Mean (L)	Mean (R)	Median (L)	Median (R)	SD (L)	SD (R)	CV (L)	CV (R)
Bank Height[1] (m)	11	11	0.96	0.95	1.31	1.40	1.22	1.14	1.25	1.12	0.10	0.13	0.09	0.11
Bankfull Height[1,2] (m)	2	0	0.57	0.00	0.59	0.00	0.58	–	0.58	–	0.01	–	0.02	–
Channel-full Height[1,2] (m)	11	11	1.02	1.02	1.59	1.57	1.32	1.24	1.34	1.22	0.15	0.18	0.11	0.15
Water Depth at Base[3] (m)	11	11	-0.15	-0.12	0.04	0.20	-0.05	-0.01	-0.05	-0.04	0.05	0.09	–	–
Bank Undercut[2] (m)	2	6	0.14	0.19	0.90	0.92	0.52	0.34	0.52	0.22	0.54	0.29	1.03	0.86
Bank Angle (°)	11	11	13	17	84	105	40	58	33	54	23	29	0.58	0.50
Vegetation Cover (%)	11	11	0	5	50	50	28	27	25	30	18	17	0.65	0.62
Bank Stability[4]	11	11	Unstable	Unstable	Unstable	Very Unstable	Unstable	Unstable	Unstable	Unstable	1.32	1.32	0.10	0.10

[1] above thalweg.

[2] statistics are based on the transects where feature is present (# in parentheses).

[3] a negative number indicates base of bank is above the water surface.

[4] see Table 1 for explanation of scores.

Table H-6. Cross-sectional characteristics for detailed transect 1 at CHAT005 [m—meter].

Type	Area (m^2)	Perimeter (m)	Hydraulic Radius (m)	Width (m)	Depth (m)	Width/Depth
Bankfull	1.22	3.60	0.34	3.22	0.58	5.55
Channel-full	4.55	6.26	0.73	5.18	1.35	3.82
Bankfull and Channel–full Ratio	3.73	1.74	2.14	1.61	2.33	0.69

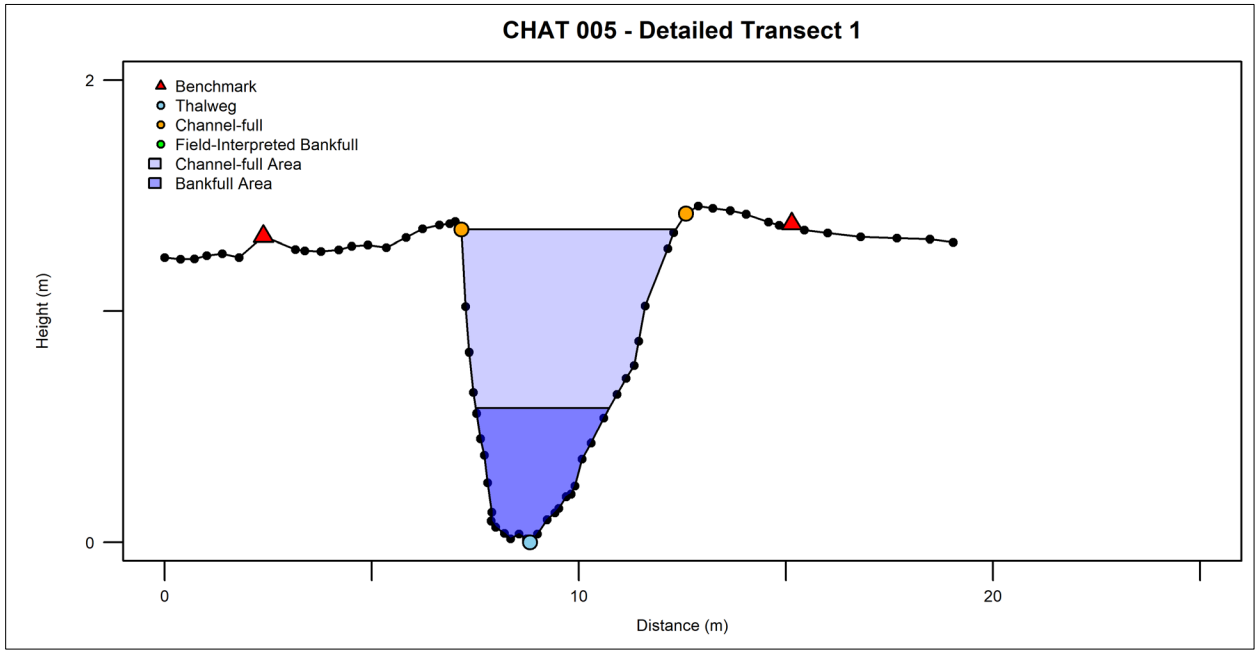


Figure H-14. Detailed transect 1 at CHAT005. The surveyed locations of the left and right benchmarks, channel-full bank-tops, and interpreted bankfull bank height are shown on the figure. Additionally, the channel-full (light blue) and bankfull (dark blue) cross-sectional areas are also included (channel-full cross-sectional area equals light blue plus dark blue).

Table H-7. Cross-sectional characteristics for detailed transect 2 at CHAT005 [m—meter].

Type	Area (m^2)	Perimeter (m)	Hydraulic Radius (m)	Width (m)	Depth (m)	Width/Depth
Bankfull	1.71	4.68	0.37	4.30	0.58	7.41
Channel-full	4.33	6.61	0.66	5.86	1.10	5.32
Bankfull and Channel–full Ratio	2.53	1.41	1.79	1.36	1.90	0.72

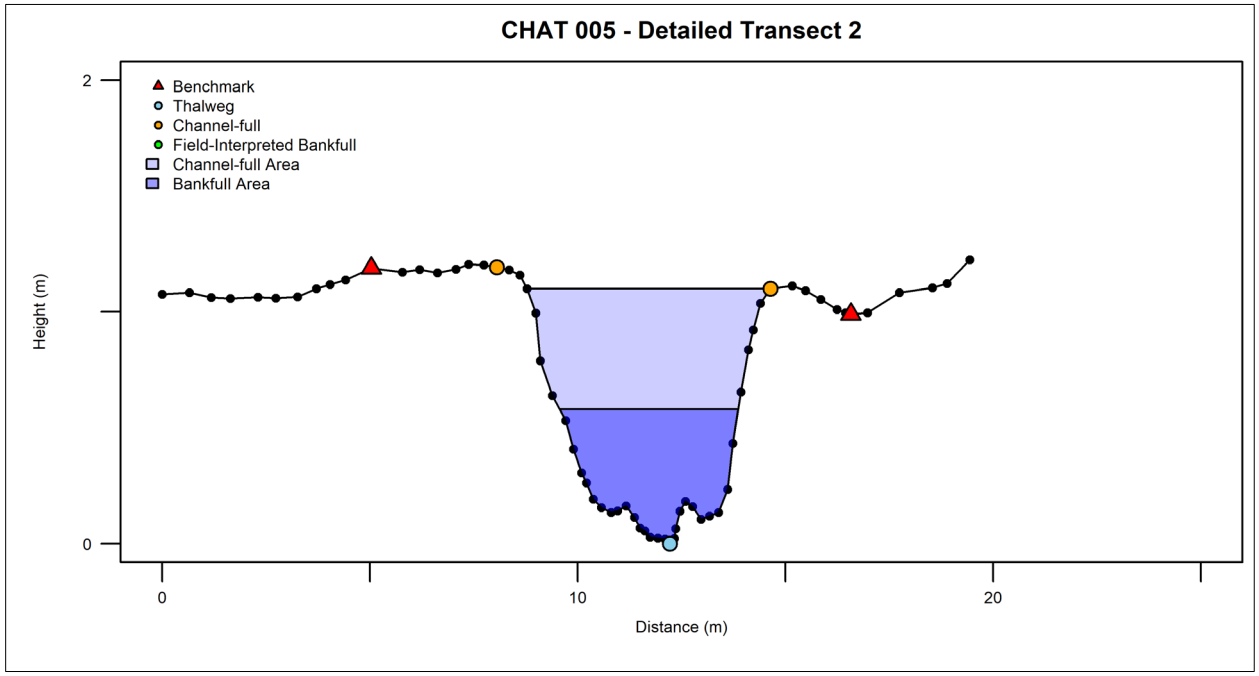


Figure H-15. Detailed transect 2 at CHAT005. The surveyed locations of the left and right benchmarks, channel-full bank-tops, and bankfull bank height are shown on the figure. Channel-full (light blue) and bankfull (dark blue) cross-sectional areas are also included (channel-full cross-sectional area equals light blue plus dark blue).

Table H-8. Cross-sectional characteristics for detailed transect 3 at CHAT005 [m—meter].

Type	Area (m^2)	Perimeter (m)	Hydraulic Radius (m)	Width (m)	Depth (m)	Width/Depth
Bankfull	1.93	4.62	0.42	3.96	0.58	6.83
Channel-full	3.79	6.12	0.62	4.90	1.02	4.80
Bankfull and Channel–full Ratio	1.96	1.33	1.48	1.24	1.76	0.70

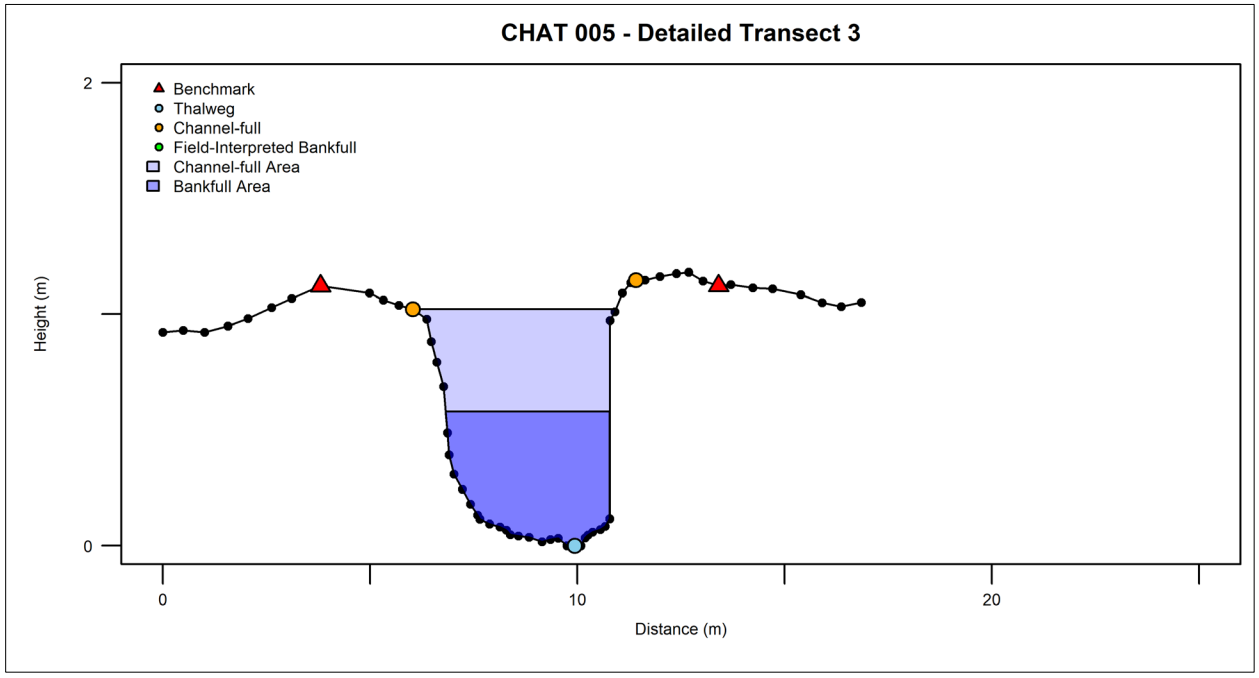


Figure H-16. Detailed transect 3 at CHAT005. The surveyed locations of the left and right benchmarks, channel-full bank-tops, and interpreted bankfull bank height are shown on the figure. Channel-full (light blue) and bankfull (dark blue) cross-sectional areas are also included (channel-full cross-sectional area equals light blue plus dark blue).

Literature Cited

Fry, J. A., G. Xian, S. Jin, J. A. Dewitz, C. G. Homer, L. Yang, C. A. Barnes, N. D. Herold, J. D. Wickham. 2006. Completion of the 2006 National Land Cover Database for the conterminous United States: Photogrammetric Engineering and Remote Sensing, v. 77, no. 9, p. 858–864.

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Homer, C. G., J. A. Dewitz, L. Yang, S. Jin, P. Danielson, G. Xian, J. Coulston, N. D. Herold, J. D. Wickham, and K. Megown. 2015. Completion of the 2011 national land cover database for the conterminous United States—representing a decade of land cover change information. Photogrammetric Engineering and Remote Sensing. 81:345–354.

United States Census Bureau (USCB). 2011. TIGER/Line Shapefiles-all roads, county-based. Available at https://www.census.gov/geographies/mapping-files/time-series/geo/tiger-line-file.2011.html (last accessed September 2019).

Appendix I. Survey Results for CHAT007

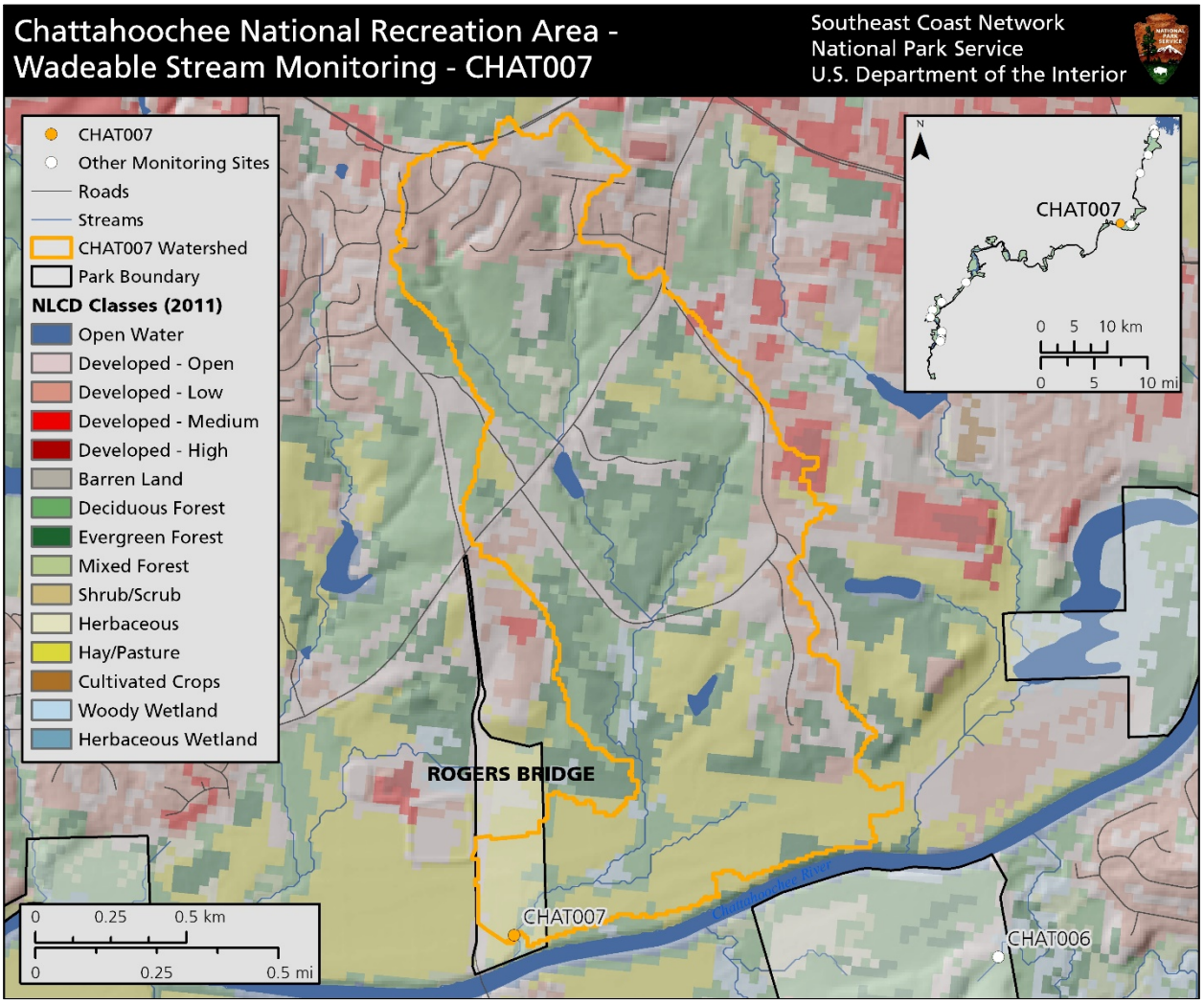


Figure I-1. Map showing the watershed draining to CHAT007 at Chattahoochee National Recreation Area. The land use/land cover (NLCD 2011, Homer et al. 2015), road network (USCB 2011), and perennial streams (derived from a 10-meter [32.8-feet] digital elevation model; data available from the U.S. Geological Survey) in the vicinity of the park are also shown.



Figure I-2. Photograph taken on CHAT007 looking upstream from T1 (detailed transect 1).



Figure I-3. Photograph taken on CHAT007 looking downstream from T1 (detailed transect 1).



Figure I-4. Photograph taken on CHAT007 looking at the left bank from T1 (detailed transect 1).



Figure I-5. Photograph taken on CHAT007 looking at the right bank from T1 (detailed transect 1).



Figure I-6. Photograph taken on CHAT007 looking upstream from T6 (detailed transect 2).



Figure I-7. Photograph taken on CHAT007 looking downstream from T6 (detailed transect 2).



Figure I-8. Photograph taken on CHAT007 looking at the left bank from T6 (detailed transect 2).



Figure I-9. Photograph taken on CHAT007 looking at the right bank from T6 (detailed transect 2).



Figure I-10. Photograph taken on CHAT007 looking upstream from T11 (detailed transect 3).



Figure I-11. Photograph taken on CHAT007 looking downstream from T11 (detailed transect 3).



Figure I-12. Photograph taken on CHAT007 looking at the left bank from T11 (detailed transect 3).



Figure I-13. Photograph taken on CHAT007 looking at the right bank from T11 (detailed transect 3).

Table I-1. Land use/land cover characteristics for 2001, 2006, and 2011 for CHAT007. The data included in this table are from the National Land Cover Dataset (Fry et al. 2001; Homer et al. 2006; Homer et al. 2015).

NLCD Class	2001 percent of watershed	2006 percent of watershed	2011 percent of watershed
Open Water	0	0	0
Developed - Open[1]	17	17	17
Developed - Low[1]	12	12	13
Developed - Medium[1]	0	0	1
Developed - High[1]	0	0	0
Barren	0	0	0
Deciduous	28	28	28
Evergreen	14	14	15
Mixed Forest	0	0	0
Shrub	0	0	0
Grassland	0	1	1
Pasture	26	26	25
Cultivated	0	0	0
Woody Wetland	1	1	1
Herbaceous Wetland	0	0	0

[1] refers to the intensity or type of development.

Table I-2. Geomorphic channel units (GCU) observed in the area between transects at CHAT007. The data describe the percent coverage of each type of GCU. [SD—Standard deviation].

Transect	(%) Riffle	(%) Run	(%) Glide	(%) Pool	(%) Step
1–2	15	20	0	65	0
2–3	60	30	0	10	0
3–4	0	40	0	60	0
4–5	40	60	0	0	0
5–6	40	60	0	0	0
6–7	0	35	0	65	0
7–8	80	10	0	10	0

Table I-2 (continued). Geomorphic channel units (GCU) observed in the area between transects at CHAT007. The data describe the percent coverage of each type of GCU. [SD—Standard deviation].

Transect	(%) Riffle	(%) Run	(%) Glide	(%) Pool	(%) Step
8–9	0	70	0	30	0
9–10	0	60	0	40	0
10–11	0	60	0	40	0
Frequency	5	10	0	8	0
Max (%)	80	70	0	65	0
Mean (%)	24	45	0	32	0
Median (%)	8	50	0	35	0
SD (%)	30	20	0	26	0

Table I-3. Characteristics of the large woody debris (LWD) observed at CHAT007 [m—meters].

LWD ID	Length (m)	Diameter (m)	Volume (m^3)	Transect Interval	Function	Position
1	1.96	0.17	0.04	11	Bank Protection	Buried
2	3.34	0.20	0.10	10	Pool formation	Step
3	1.93	0.21	0.07	10	Bank Protection	Buried
4	2.09	0.09	0.01	10	Bank Protection, Sediment trap	Buried
5	3.75	0.36	0.38	6	Jam, Organic trap, Sediment trap, Pool formation	Jam
6	4.73	0.28	0.29	4	Bank Protection, Sediment trap	Buried
7	11.15	0.22	0.42	3	Pool formation, Sediment trap, Bank Protection	Buried
8	2.00	0.19	0.06	3	Bank Protection, Sediment trap, Organic trap	Buried
9	1.93	0.34	0.18	2	Bank Protection	Buried
10	1.54	0.17	0.03	1	None	Free
11	4.21	0.25	0.21	1	Bank Protection	Free

Table I-4. Variability of canopy cover observed at CHAT007 [SD—Standard deviation; CV—Coefficient of variation].

Transect	Canopy Cover (%)
1	85
2	88
3	82
4	82
5	93
6	88
7	93
8	91
9	82
10	90
11	91
Min (%)	82
Max (%)	93
Mean (%)	88
Median (%)	88
SD (%)	4
CV	0.05

Table I-5. Average reach-scale bank characteristics at CHAT007. [L indicates left bank and R indicates right bank; SD—Standard deviation; Coefficient of variation; m—meters].

Bank Characteristics	n (L)	n (R)	Min (L)	Min (R)	Max (L)	Max (R)	Mean (L)	Mean (R)	Median (L)	Median (R)	SD (L)	SD (R)	CV (L)	CV (R)
Bank Height[1] (m)	11	11	0.47	0.61	4.19	2.56	1.62	1.31	1.01	1.13	1.25	0.68	0.77	0.52
Bankfull Height[1,2] (m)	3	4	0.37	0.39	0.57	0.78	0.47	0.60	0.48	0.61	0.10	0.16	0.21	0.27
Channel-full Height[1,2] (m)	11	11	0.56	0.70	4.30	2.69	1.78	1.47	1.21	1.35	1.26	0.68	0.70	0.46
Water Depth at Base[3] (m)	11	11	-0.26	-0.26	0.05	0.09	-0.08	-0.09	-0.05	-0.08	0.09	0.10	–	–
Bank Undercut[2] (m)	3	0	0.11	0.00	0.27	0.00	0.17	–	0.13	–	0.09	–	–	–
Bank Angle (°)	11	11	30	22	78	82	55	45	64	47	17	19	0.31	0.42
Vegetation Cover (%)	11	11	0	5	50	90	13	18	5	10	18	24	1.39	1.38
Bank Stability[4]	11	11	At-Risk	At-Risk	Very Unstable	Unstable	Unstable	Unstable	Unstable	Unstable	2.24	1.40	0.18	0.11

[1] above thalweg.

[2] statistics are based on the transects where feature is present (# in parentheses).

[3] a negative number indicates base of bank is above the water surface.

[4] see Table 1 for explanation of scores.

Table I-6. Cross-sectional characteristics for detailed transect 1 at CHAT007 [m—meter].

Type	Area (m^2)	Perimeter (m)	Hydraulic Radius (m)	Width (m)	Depth (m)	Width/Depth
Bankfull	1.29	4.24	0.30	3.82	0.49	7.81
Channel-full	4.95	8.73	0.57	8.13	1.07	7.56
Bankfull and Channel–full Ratio	3.83	2.06	1.86	2.13	2.19	0.97

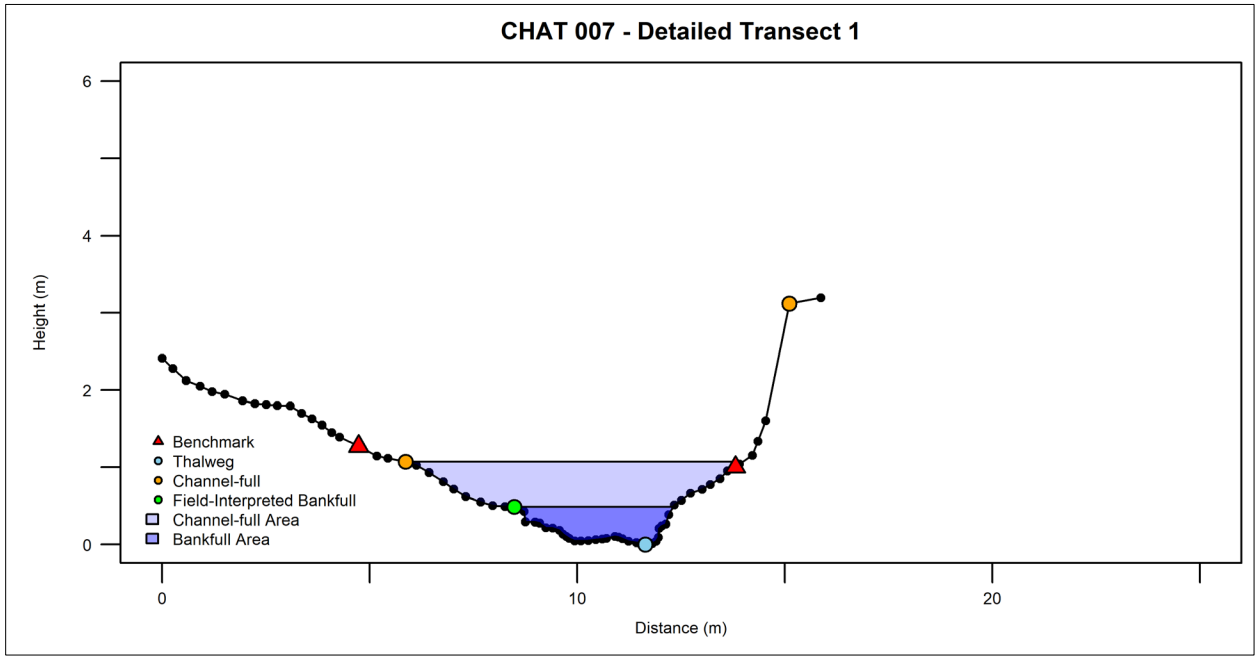


Figure I-14. Detailed transect 1 at CHAT007. The surveyed locations of the left and right benchmarks, channel-full bank-tops, and interpreted bankfull bank height are shown on the figure. Additionally, the channel-full (light blue) and bankfull (dark blue) cross-sectional areas are also included (channel-full cross-sectional area equals light blue plus dark blue).

Table I-7. Cross-sectional characteristics for detailed transect 2 at CHAT007 [m—meter].

Type	Area (m^2)	Perimeter (m)	Hydraulic Radius (m)	Width (m)	Depth (m)	Width/Depth
Bankfull	1.30	4.40	0.29	4.24	0.49	8.70
Channel-full	5.85	10.13	0.58	9.66	1.19	8.09
Bankfull and Channel–full Ratio	4.51	2.30	1.96	2.28	2.45	0.93

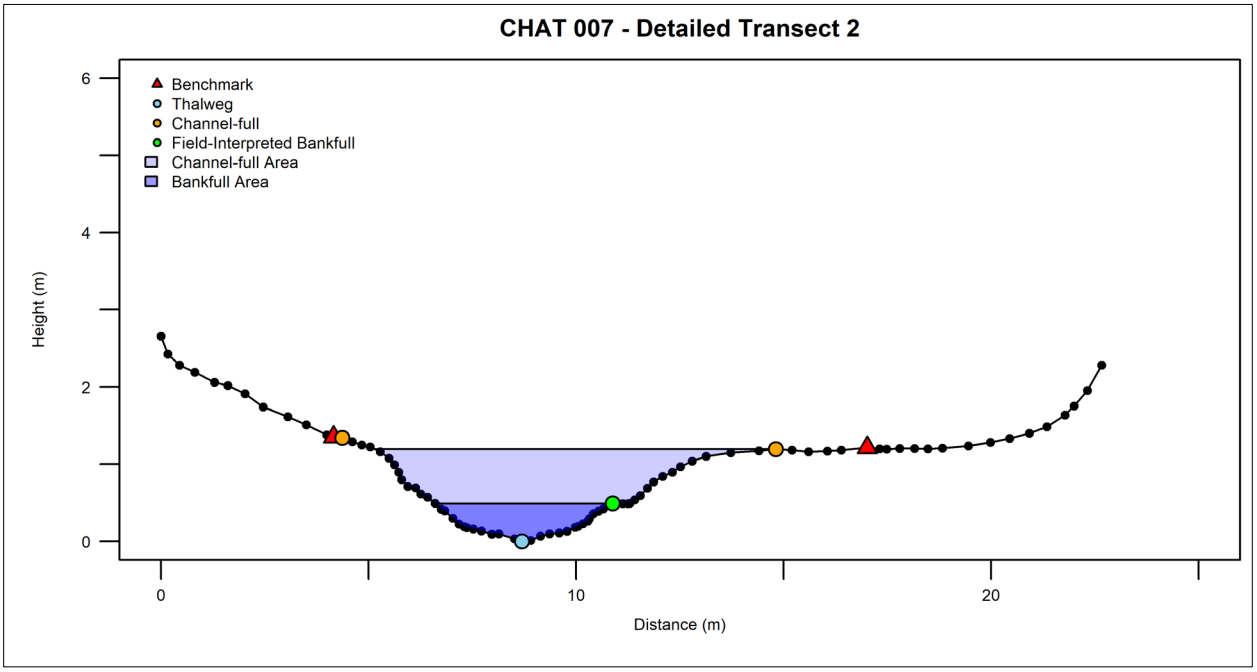


Figure I-15. Detailed transect 2 at CHAT007. The surveyed locations of the left and right benchmarks, channel-full bank-tops, and bankfull bank height are shown on the figure. Channel-full (light blue) and bankfull (dark blue) cross-sectional areas are also included (channel-full cross-sectional area equals light blue plus dark blue).

Table I-8. Cross-sectional characteristics for detailed transect 3 at CHAT007 [m—meter].

Type	Area (m^2)	Perimeter (m)	Hydraulic Radius (m)	Width (m)	Depth (m)	Width/Depth
Bankfull	1.09	3.32	0.33	3.00	0.53	5.71
Channel-full	1.94	4.70	0.41	4.29	0.76	5.63
Bankfull and Channel–full Ratio	1.78	1.42	1.26	1.43	1.45	0.99

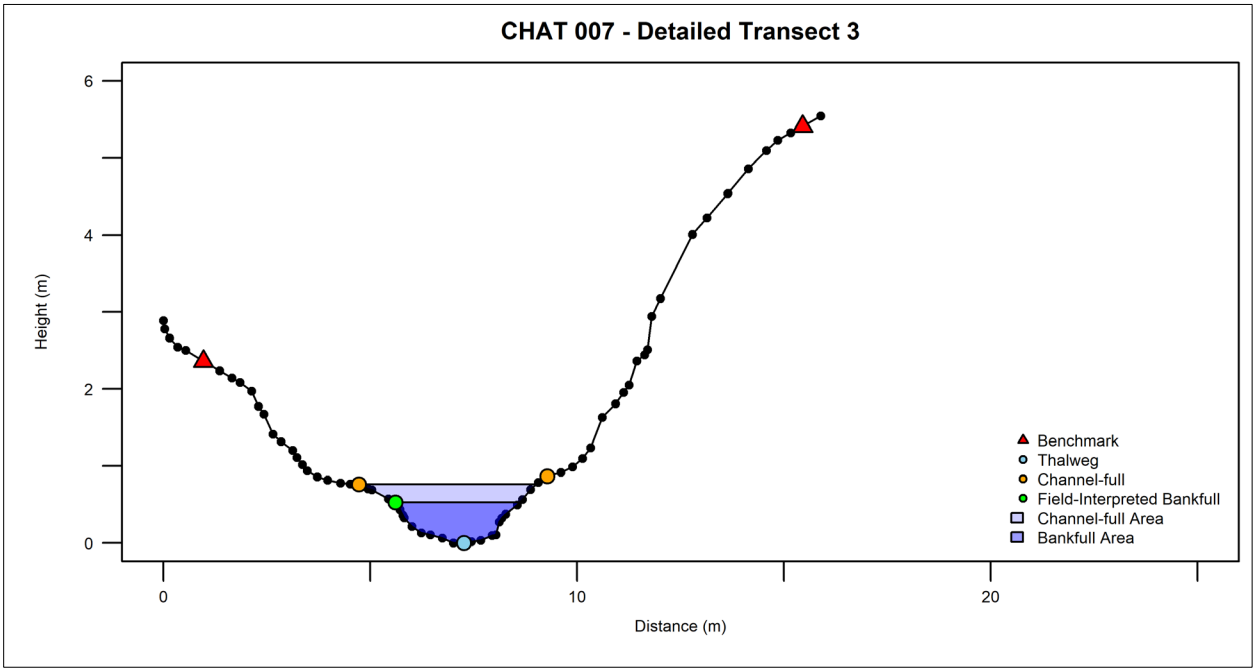


Figure I-16. Detailed transect 3 at CHAT007. The surveyed locations of the left and right benchmarks, channel-full bank-tops, and interpreted bankfull bank height are shown on the figure. Channel-full (light blue) and bankfull (dark blue) cross-sectional areas are also included (channel-full cross-sectional area equals light blue plus dark blue).

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Fry, J. A., G. Xian, S. Jin, J. A. Dewitz, C. G. Homer, L. Yang, C. A. Barnes, N. D. Herold, J. D. Wickham. 2006. Completion of the 2006 National Land Cover Database for the conterminous United States: Photogrammetric Engineering and Remote Sensing, v. 77, no. 9, p. 858–864.

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Appendix J. Survey Results for CHAT008

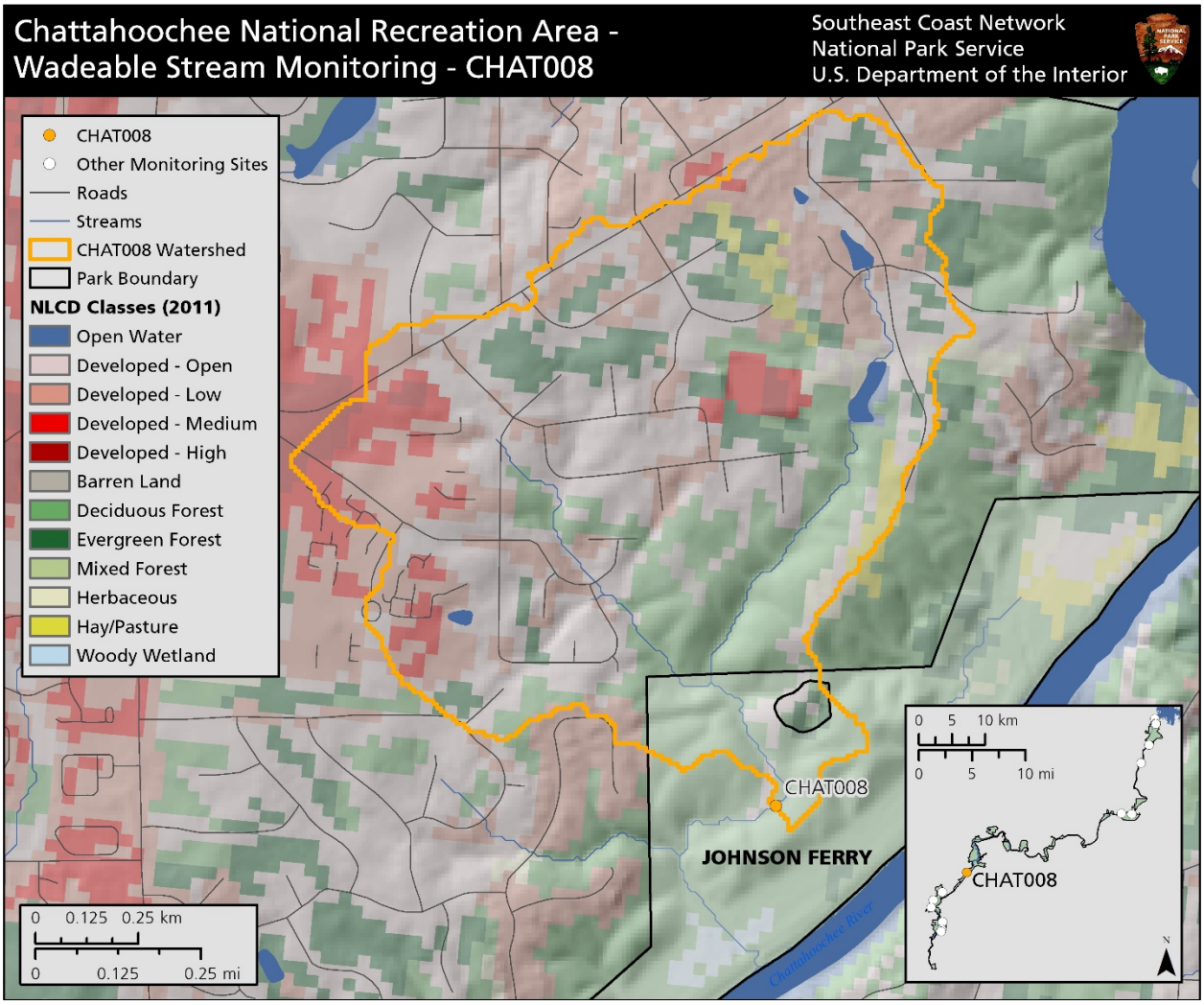


Figure J-1. Map showing the watershed draining to CHAT008 at Chattahoochee National Recreation Area. The land use/land cover (NLCD 2011, Homer et al. 2015), road network (USCB 2011), and perennial streams (derived from a 10-meter [32.8-feet] digital elevation model; data available from the U.S. Geological Survey) in the vicinity of the park are also shown.



Figure J-2. Photograph taken on CHAT008 looking upstream from T1 (detailed transect 1).



Figure J-3. Photograph taken on CHAT008 looking downstream from T1 (detailed transect 1).



Figure J-4. Photograph taken on CHAT008 looking at the left bank from T1 (detailed transect 1).



Figure J-5. Photograph taken on CHAT008 looking at the right bank from T1 (detailed transect 1).



Figure J-6. Photograph taken on CHAT008 looking upstream from T6 (detailed transect 2).



Figure J-7. Photograph taken on CHAT008 looking downstream from T6 (detailed transect 2).



Figure J-8. Photograph taken on CHAT008 looking at the left bank from T6 (detailed transect 2).



Figure J-9. Photograph taken on CHAT008 looking at the right bank from T6 (detailed transect 2).



Figure J-10. Photograph taken on CHAT008 looking upstream from T11 (detailed transect 3).



Figure J-11. Photograph taken on CHAT008 looking downstream from T11 (detailed transect 3).



Figure J-12. Photograph taken on CHAT008 looking at the left bank from T11 (detailed transect 3).



Figure J-13. Photograph taken on CHAT008 looking at the right bank from T11 (detailed transect 3).

Table J-1. Land use/land cover characteristics for 2001, 2006, and 2011 for CHAT008. The data included in this table are from the National Land Cover Dataset (Fry et al. 2001; Homer et al. 2006; Homer et al. 2015).

NLCD Class	2001 percent of watershed	2006 percent of watershed	2011 percent of watershed
Open Water	0	0	0
Developed - Open[1]	35	34	34
Developed - Low[1]	23	23	22
Developed - Medium[1]	4	4	5
Developed - High[1]	1	1	1
Barren	0	0	0
Deciduous	23	23	23
Evergreen	9	9	9
Mixed Forest	0	0	0
Shrub	0	0	0
Grassland	1	1	1
Pasture	2	2	2
Cultivated	0	0	0
Woody Wetland	0	0	0
Herbaceous Wetland	0	0	0

Table J-2. Geomorphic channel units (GCU) observed in the area between transects at CHAT008. The data describe the percent coverage of each type of GCU [SD—Standard deviation].

Transect	(%) Riffle	(%) Run	(%) Glide	(%) Pool	(%) Step
1–2	0	0	0	100	0
2–3	0	25	0	75	0
3–4	20	10	0	70	0
4–5	70	0	0	30	0
5–6	100	0	0	0	0
6–7	50	0	0	50	0
7–8	0	0	0	100	0

Table J-2 (continued). Geomorphic channel units (GCU) observed in the area between transects at CHAT008. The data describe the percent coverage of each type of GCU [SD—Standard deviation].

Transect	(%) Riffle	(%) Run	(%) Glide	(%) Pool	(%) Step
8–9	40	0	0	60	0
9–10	100	0	0	0	0
10–11	30	70	0	0	0
Frequency	7	3	0	7	0
Max (%)	100	70	0	100	0
Mean (%)	41	11	0	49	0
Median (%)	35	0	0	55	0
SD (%)	39	22	0	39	0

Table J-3. Characteristics of the large woody debris (LWD) observed at CHAT008 [m—meter].

LWD ID	Length (m)	Diameter (m)	Volume (m^3)	Transect Interval	Function	Position
1	1.45	0.12	0.02	9	Bank Protection	Buried
2	5.53	0.18	0.14	8	None	Free
3	5.05	0.14	0.08	5	Organic trap	Free
4	5.07	0.43	0.74	5	Organic trap, Pool formation, Sediment trap	Ramp
5	2.86	0.16	0.06	2	Jam, Sediment trap, Organic trap, Pool formation	Jam
6	1.73	0.16	0.03	2	Sediment trap	Buried

Table J-4. Variability of canopy cover observed at CHAT008 [SD—Standard deviation; CV—Coefficient of variation; m—meters].

Transect	Canopy Cover (%)
1	94
2	90
3	90
4	90
5	96
6	96
7	93
8	93
9	90
10	94
11	94
Min (%)	90
Max (%)	96
Mean (%)	93
Median (%)	93
SD (%)	2
CV	0.03

Table J-5. Average reach-scale bank characteristics at CHAT008. [L indicates left bank and R indicates right bank; SD—Standard deviation; CV—Coefficient of variation; m—meters].

Bank Characteristics	n (L)	n (R)	Min (L)	Min (R)	Max (L)	Max (R)	Mean (L)	Mean (R)	Median (L)	Median (R)	SD (L)	SD (R)	CV (L)	CV (R)
Bank Height[1] (m)	11	11	0.72	0.60	1.55	1.55	1.19	1.15	1.31	1.30	0.32	0.36	0.27	0.31
Bankfull Height[1,2] (m)	4	2	0.38	0.51	1.03	0.60	0.68	0.56	0.66	0.56	0.34	0.06	0.50	0.11
Channel-full Height[1,2] (m)	11	11	0.80	0.66	1.73	1.95	1.38	1.35	1.48	1.42	0.34	0.44	0.25	0.32
Water Depth at Base[3] (m)	11	11	-0.11	-0.20	0.04	0.43	-0.03	-0.01	-0.04	-0.03	0.05	0.16	–	–
Bank Undercut[2] (m)	5	3	0.09	0.07	0.50	0.58	0.22	0.28	0.19	0.19	0.16	0.27	0.73	0.95
Bank Angle (°)	11	11	11	14	84	90	54	58	59	60	30	26	0.56	0.45
Vegetation Cover (%)	11	11	5	5	80	80	39	35	40	20	22	27	0.55	0.77
Bank Stability[4]	11	11	Unstable	At-Risk	Unstable	Very Unstable	Unstable	Unstable	Unstable	Unstable	1.23	1.97	0.09	0.15

[1] above thalweg.

[2] statistics are based on the transects where the feature is present (# in parentheses).

[3] a negative number indicates base of bank is above the water service.

[4] see Table 1 for explanation of scores.

Table J-6. Cross-sectional characteristics for detailed transect 1 at CHAT008 [m—meter].

Type	Area (m^2)	Perimeter (m)	Hydraulic Radius (m)	Width (m)	Depth (m)	Width/Depth
Bankfull	0.41	3.18	0.13	3.10	0.18	17.44
Channel-full	1.62	4.95	0.33	4.62	0.47	9.90
Bankfull and Channel–full Ratio	3.99	1.56	2.56	1.49	2.63	0.57

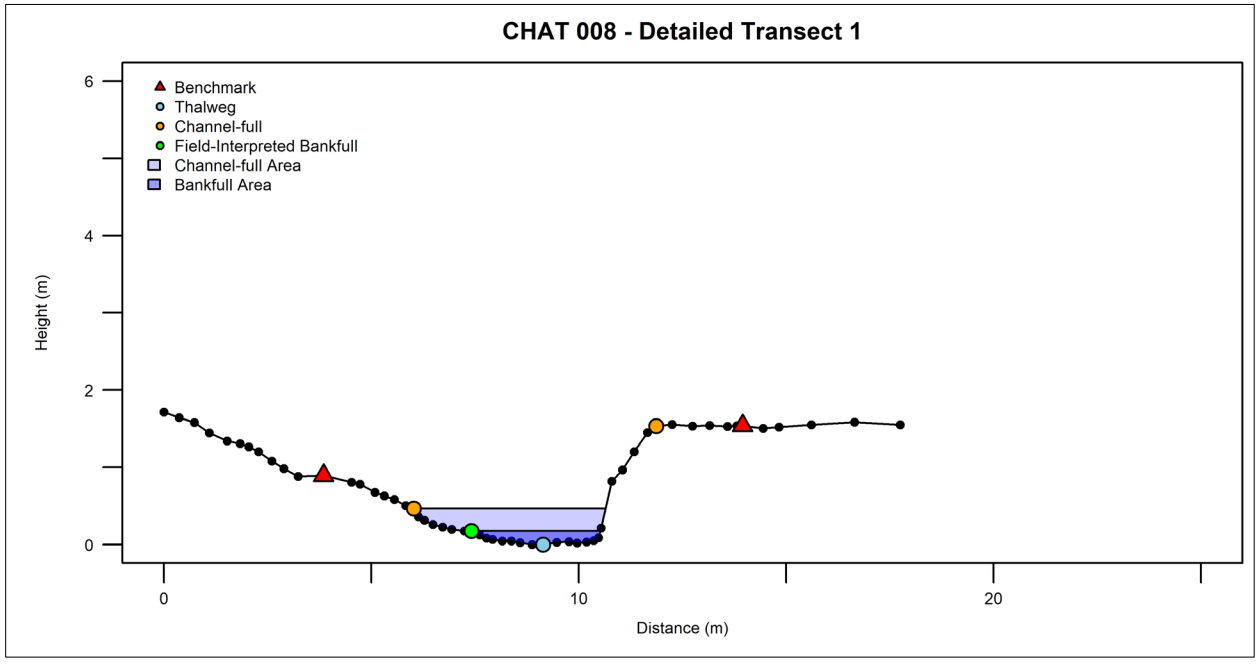


Figure J-14. Detailed transect 1 at CHAT008. The surveyed locations of the left and right benchmarks, channel-full bank-tops, and interpreted bankfull bank height are shown on the figure. Additionally, the channel-full (light blue) and bankfull (dark blue) cross-sectional areas are also included (channel-full cross-sectional area equals light blue plus dark blue).

Table J-7. Cross-sectional characteristics for detailed transect 2 at CHAT008 [m—meter].

Type	Area (m^2)	Perimeter (m)	Hydraulic Radius (m)	Width (m)	Depth (m)	Width/Depth
Bankfull	2.58	6.87	0.38	6.17	0.56	11.02
Channel-full	2.80	6.96	0.40	6.21	0.60	10.44
Bankfull and Channel–full Ratio	1.08	1.01	1.07	1.01	1.06	0.95

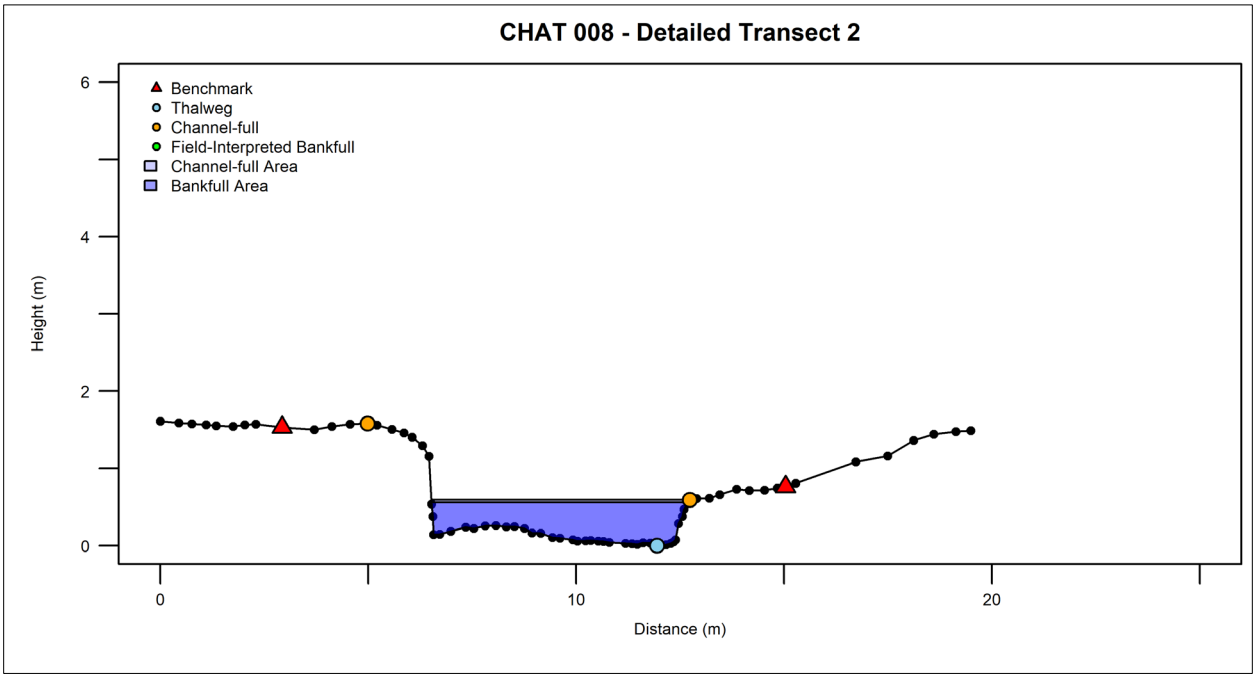


Figure J-15. Detailed transect 2 at CHAT008. The surveyed locations of the left and right benchmarks, channel-full bank-tops, and bankfull bank height are shown on the figure. Channel-full (light blue) and bankfull (dark blue) cross-sectional areas are also included (channel-full cross-sectional area equals light blue plus dark blue).

Table J-8. Cross-sectional characteristics for detailed transect 3 at CHAT008 [m—meter].

Type	Area (m^2)	Perimeter (m)	Hydraulic Radius (m)	Width (m)	Depth (m)	Width/Depth
Bankfull	1.05	6.26	0.17	6.01	0.28	21.84
Channel-full	10.69	12.62	0.85	11.73	1.28	9.19
Bankfull and Channel–full Ratio	10.21	2.02	5.07	1.95	4.64	0.42

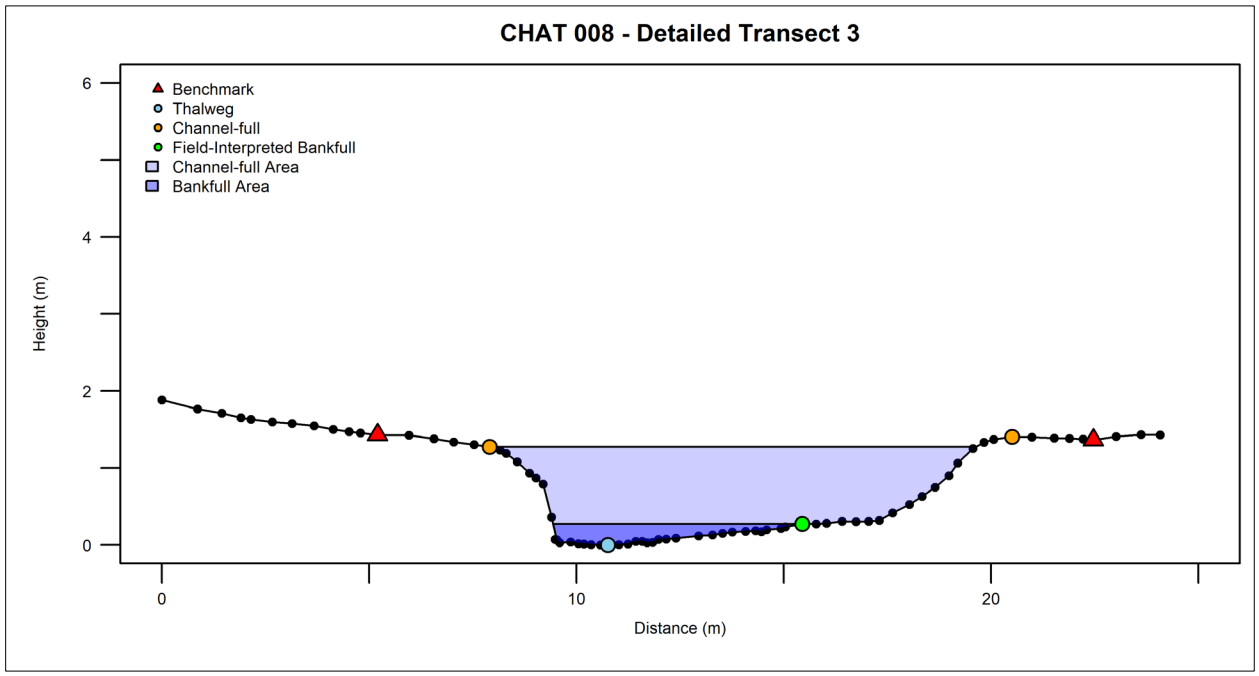


Figure J-16. Detailed transect 3 at CHAT008. The surveyed locations of the left and right benchmarks, channel-full bank-tops, and interpreted bankfull bank height are shown on the figure. Channel-full (light blue) and bankfull (dark blue) cross-sectional areas are also included (channel-full cross-sectional area equals light blue plus dark blue).

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Fry, J. A., G. Xian, S. Jin, J. A. Dewitz, C. G. Homer, L. Yang, C. A. Barnes, N. D. Herold, J. D. Wickham. 2006. Completion of the 2006 National Land Cover Database for the conterminous United States: Photogrammetric Engineering and Remote Sensing, v. 77, no. 9, p. 858–864.

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Homer, C. G., J. A. Dewitz, L. Yang, S. Jin, P. Danielson, G. Xian, J. Coulston, N. D. Herold, J. D. Wickham, and K. Megown. 2015. Completion of the 2011 national land cover database for the conterminous United States—representing a decade of land cover change information. Photogrammetric Engineering and Remote Sensing. 81:345–354.

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Appendix K. Survey Results for CHAT010

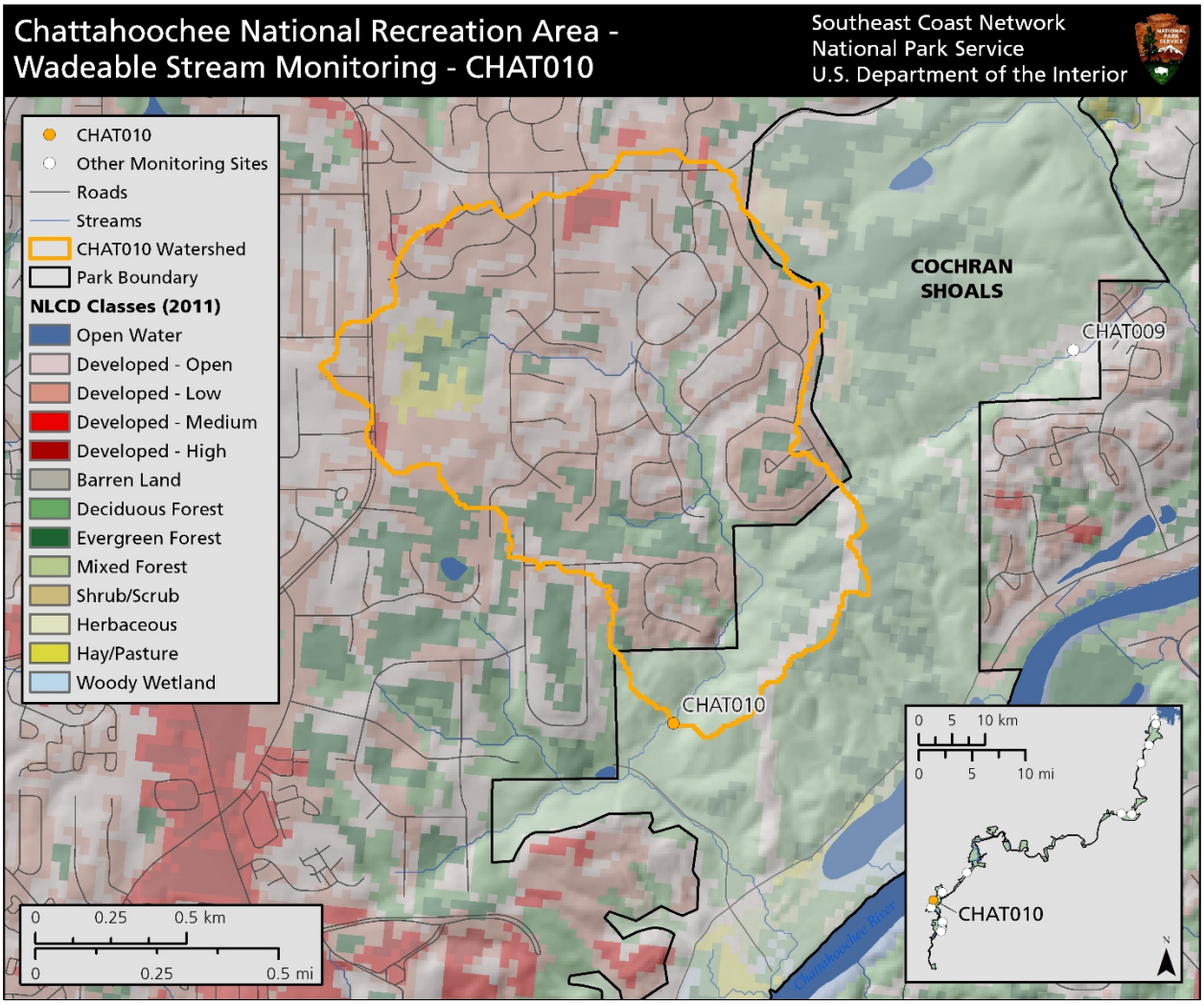


Figure K-1. Map showing the watershed draining to CHAT010 at Chattahoochee National Recreation Area. The land use/land cover (NLCD 2011, Homer et al. 2015), road network (USCB 2011), and perennial streams (derived from a 10-meter [32.8-feet] digital elevation model; data available from the U.S. Geological Survey) in the vicinity of the park are also shown.



Figure K-2. Photograph taken on CHAT010 looking upstream from T1 (detailed transect 1).



Figure K-3. Photograph taken on CHAT010 looking downstream from T1 (detailed transect 1).



Figure K-4. Photograph taken on CHAT010 looking at the left bank from T1 (detailed transect 1).



Figure K-5. Photograph taken on CHAT010 looking at the right bank from T1 (detailed transect 1).

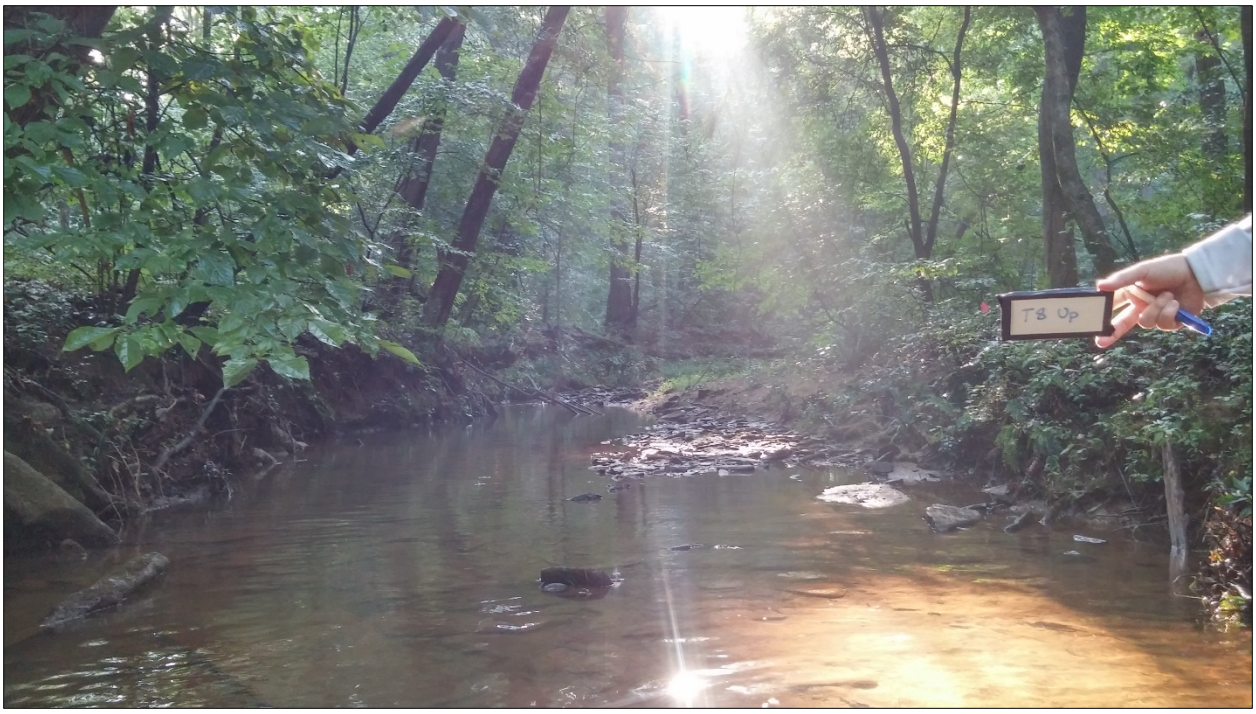


Figure K-6. Photograph taken on CHAT010 looking upstream from T8 (detailed transect 2).



Figure K-7. Photograph taken on CHAT010 looking downstream from T8 (detailed transect 2).



Figure K-8. Photograph taken on CHAT010 looking at the left bank from T8 (detailed transect 2).



Figure K-9. Photograph taken on CHAT010 looking at the right bank from T8 (detailed transect 2).



Figure K-10. Photograph taken on CHAT010 looking upstream from T10 (detailed transect 3).



Figure K-11. Photograph taken on CHAT010 looking downstream from T10 (detailed transect 3).



Figure K-12. Photograph taken on CHAT010 looking at the left bank from T10 (detailed transect 3).



Figure K-13. Photograph taken on CHAT010 looking at the right bank from T10 (detailed transect 3).

Table K-1. Land use/land cover characteristics for 2001, 2006, and 2011 for CHAT010. The data included in this table are from the National Land Cover Dataset (Fry et al. 2001; Homer et al. 2006; Homer et al. 2015).

NLCD Class	2001 percent of watershed	2006 percent of watershed	2011 percent of watershed
Open Water	0	0	0
Developed - Open[1]	29	29	30
Developed - Low[1]	39	39	39
Developed - Medium[1]	1	1	1
Developed - High[1]	1	1	1
Barren	0	0	0
Deciduous	13	13	13
Evergreen	14	14	14
Mixed Forest	0	0	0
Shrub	0	0	0
Grassland	0	0	0
Pasture	2	2	2
Cultivated	0	0	0
Woody Wetland	0	0	0
Herbaceous Wetland	0	0	0

[1] refers to the intensity or type of development.

Table K-2. Geomorphic channel units (GCU) observed in the area between transects at CHAT010. The data describe the percent coverage of each type of GCU [SD—Standard deviation].

Transect	(%) Riffle	(%) Run	(%) Glide	(%) Pool	(%) Step
1–2	60	0	0	40	0
2–3	0	15	0	85	0
3–4	75	10	0	15	0
4–5	0	0	0	100	0
5–6	0	0	0	100	0
6–7	100	0	0	0	0
7–8	25	75	0	0	0

Table K-2 (continued). Geomorphic channel units (GCU) observed in the area between transects at CHAT010. The data describe the percent coverage of each type of GCU [SD—Standard deviation]..

Transect	(%) Riffle	(%) Run	(%) Glide	(%) Pool	(%) Step
8–9	0	100	0	0	0
9–10	0	0	0	100	0
10–11	40	0	0	60	0
Frequency	5	4	0	7	0
Max (%)	100	100	0	100	0
Mean (%)	30	20	0	50	0
Median (%)	13	0	0	50	0
SD (%)	37	36	0	44	0

Table K-3. Characteristics of the large woody debris (LWD) observed at CHAT010 [m—meter].

LWD ID	Length (m)	Diameter (m)	Volume (m^3)	Transect Interval	Function	Position
1	2.10	0.13	0.03	8	None	Free
2	4.02	0.16	0.08	6	None	Bridge
3	3.00	0.28	0.18	6	None	Bridge
4	3.25	0.11	0.03	5	None	Bridge
5	1.80	0.10	0.01	5	Organic trap	Buried
6	3.80	0.15	0.07	4	Organic trap, Jam	Jam
7	2.11	0.16	0.04	4	Organic trap, Jam	Jam
8	1.93	0.24	0.09	4	Organic trap, Jam	Jam
9	1.02	0.20	0.03	4	Organic trap, Jam	Jam
10	5.70	0.36	0.58	4	Organic trap, Jam	Bridge
11	3.78	0.12	0.04	4	None	Bridge
12	3.10	0.29	0.20	1	Bank Protection, Organic trap	Buried

Table K-4. Variability of canopy cover observed at CHAT010 [SD—Standard deviation; CD—Coefficient of variation].

Transect	Canopy Cover (%)
1	97
2	88
3	97
4	97
5	91
6	84
7	90
8	88
9	88
10	79
11	87
Min (%)	79
Max (%)	97
Mean (%)	90
Median (%)	88
SD (%)	6
CV	0.06

Table K-5. Average reach-scale bank characteristics at CHAT010. [L indicates left bank and R indicates right bank; SD—Standard deviation; CV—Coefficient of variation; m—meters].

Bank Characteristics	n (L)	n (R)	Min (L)	Min (R)	Max (L)	Max (R)	Mean (L)	Mean (R)	Median (L)	Median (R)	SD (L)	SD (R)	CV (L)	CV (R)
Bank Height[1] (m)	11	11	0.63	1.15	1.59	1.45	1.03	1.30	1.04	1.28	0.29	0.10	0.28	0.08
Bankfull Height[1,2] (m)	4	1	0.60	0.52	0.99	0.52	0.74	0.52	0.68	0.52	0.18	–	0.24	–
Channel-full Height[1,2] (m)	11	11	0.80	1.27	1.73	1.94	1.31	1.58	1.25	1.56	0.31	0.21	0.23	0.13
Water Depth at Base[3] (m)	11	11	-0.14	-0.11	0.00	0.50	-0.09	0.08	-0.08	0.05	0.05	0.18	–	–
Bank Undercut[2] (m)	0	7	0.00	0.07	0.00	0.52	–	0.27	–	0.25	–	0.16	–	0.59
Bank Angle (°)	11	11	13	9	74	90	29	71	18	82	21	25	0.72	0.35
Vegetation Cover (%)	11	11	5	5	70	60	31	28	25	30	22	20	0.71	0.73
Bank Stability[4]	11	11	At-Risk	At-Risk	Unstable	Unstable	Unstable	Unstable	Unstable	Unstable	2.88	1.40	0.25	0.11

[1] above thalweg.

[2] statistics are based on the transects where the feature is present (# in parentheses).

[3] a negative number indicates base of bank is above the water service.

[4] see Table 1 for explanation of scores.

Table K-6. Cross-sectional characteristics for detailed transect 1 at CHAT010 [m—meter].

Type	Area (m^2)	Perimeter (m)	Hydraulic Radius (m)	Width (m)	Depth (m)	Width/Depth
Bankfull	1.60	5.34	0.30	4.98	0.48	10.39
Channel-full	7.03	9.68	0.73	8.57	1.18	7.25
Bankfull and Channel–full Ratio	4.40	1.81	2.43	1.72	2.47	0.70

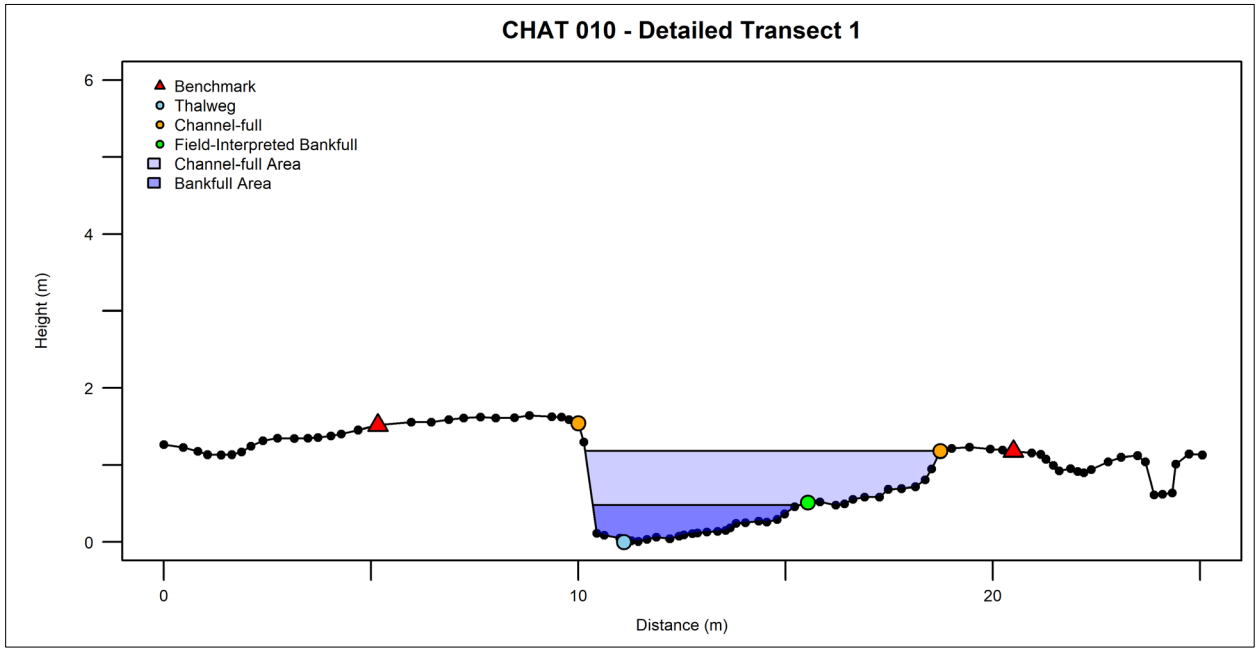


Figure K-14. Detailed transect 1 at CHAT010. The surveyed locations of the left and right benchmarks, channel-full bank-tops, and interpreted bankfull bank height are shown on the figure. Additionally, the channel-full (light blue) and bankfull (dark blue) cross-sectional areas are also included (channel-full cross-sectional area equals light blue plus dark blue).

Table K-7. Cross-sectional characteristics for detailed transect 2 at CHAT010 [m—meter].

Type	Area (m^2)	Perimeter (m)	Hydraulic Radius (m)	Width (m)	Depth (m)	Width/Depth
Bankfull	2.97	6.74	0.44	6.34	0.64	9.90
Channel-full	5.29	8.04	0.66	7.38	0.98	7.56
Bankfull and Channel–full Ratio	1.78	1.19	1.49	1.16	1.53	0.76

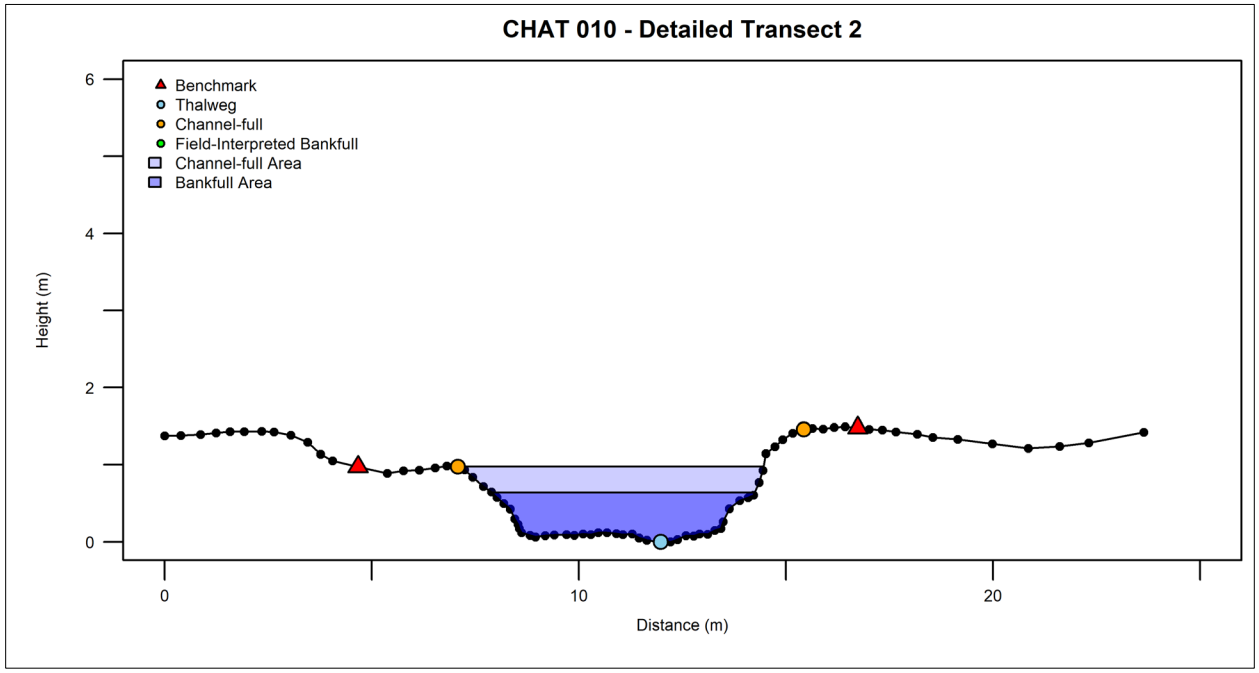


Figure K-15. Detailed transect 2 at CHAT010. The surveyed locations of the left and right benchmarks, channel-full bank-tops, and bankfull bank height are shown on the figure. Channel-full (light blue) and bankfull (dark blue) cross-sectional areas are also included (channel-full cross-sectional area equals light blue plus dark blue).

Table K-8. Cross-sectional characteristics for detailed transect 3 at CHAT010 [m—meter].

Type	Area (m^2)	Perimeter (m)	Hydraulic Radius (m)	Width (m)	Depth (m)	Width/Depth
Bankfull	1.55	4.25	0.37	3.83	0.64	5.98
Channel-full	6.72	8.76	0.77	7.70	1.54	5.00
Bankfull and Channel–full Ratio	4.33	2.06	2.10	2.01	2.41	0.84

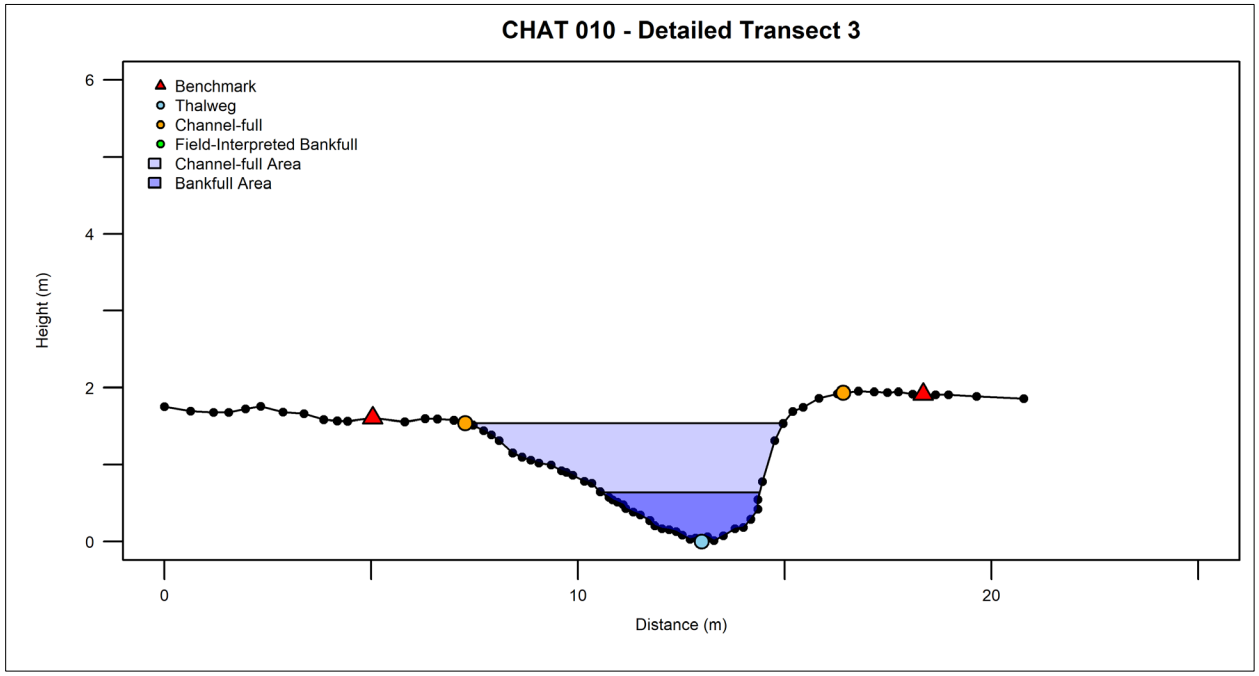


Figure K-16. Detailed transect 3 at CHAT010. The surveyed locations of the left and right benchmarks, channel-full bank-tops, and interpreted bankfull bank height are shown on the figure. Channel-full (light blue) and bankfull (dark blue) cross-sectional areas are also included (channel-full cross-sectional area equals light blue plus dark blue).

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Fry, J. A., G. Xian, S. Jin, J. A. Dewitz, C. G. Homer, L. Yang, C. A. Barnes, N. D. Herold, J. D. Wickham. 2006. Completion of the 2006 National Land Cover Database for the conterminous United States: Photogrammetric Engineering and Remote Sensing, v. 77, no. 9, p. 858–864.

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Appendix L. Survey Results for CHAT011

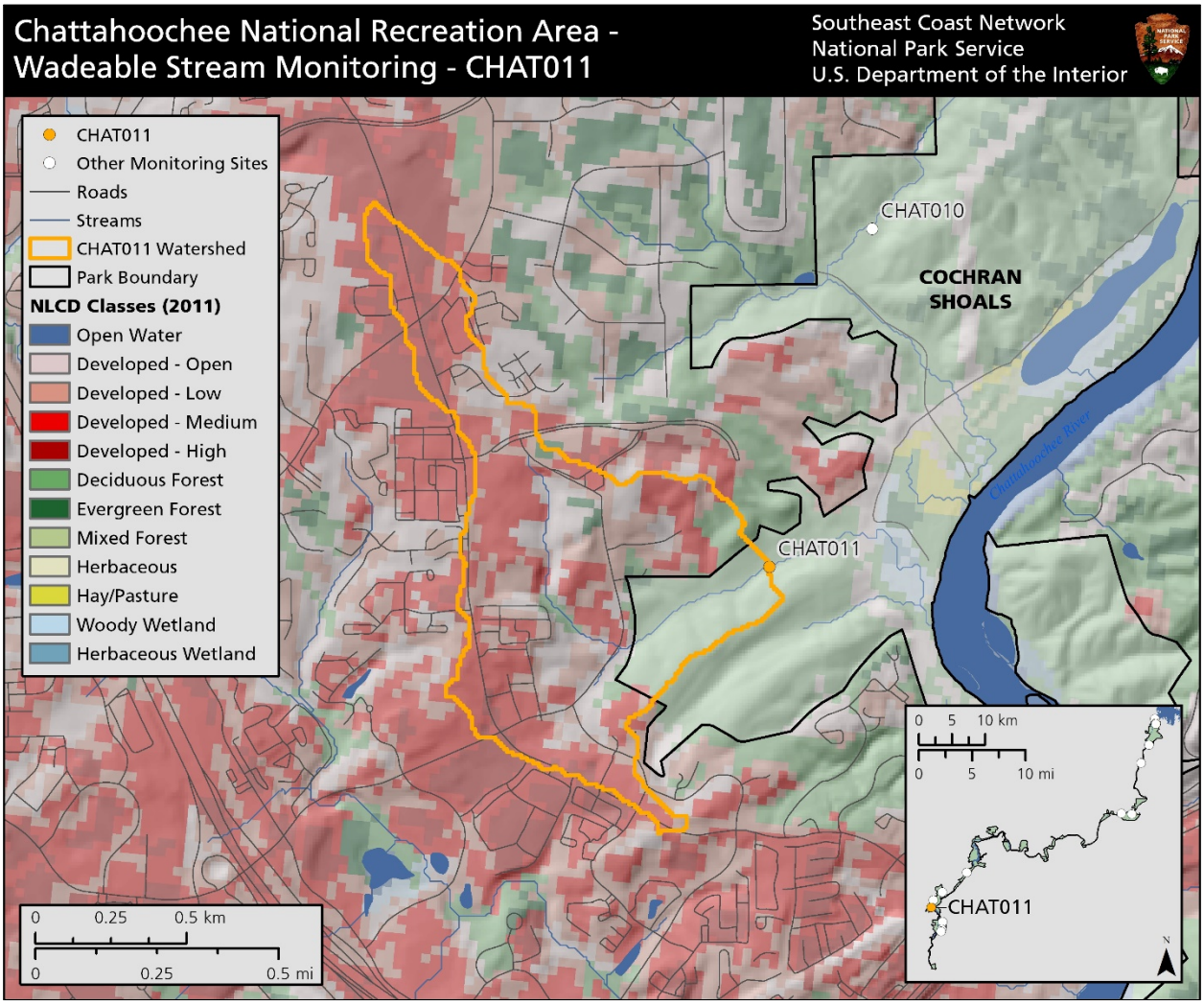


Figure L-1. Map showing the watershed draining to CHAT011 at Chattahoochee National Recreation Area. The land use/land cover (NLCD 2011, Homer et al. 2015), road network (USCB 2011), and perennial streams (derived from a 10-meter [32.8-feet] digital elevation model; data available from the U.S. Geological Survey) in the vicinity of the park are also shown.



Figure L-2. Photograph taken on CHAT011 looking upstream from T1 (detailed transect 1).



Figure L-3. Photograph taken on CHAT011 looking downstream from T1 (detailed transect 1).



Figure L-4. Photograph taken on CHAT011 looking at the left bank from T1 (detailed transect 1).



Figure L-5. Photograph taken on CHAT011 looking at the right bank from T1 (detailed transect 1).



Figure L-6. Photograph taken on CHAT011 looking upstream from T4 (detailed transect 2).



Figure L-7. Photograph taken on CHAT011 looking downstream from T4 (detailed transect 2).



Figure L-8. Photograph taken on CHAT011 looking at the left bank from T4 (detailed transect 2).



Figure L-9. Photograph taken on CHAT011 looking at the right bank from T4 (detailed transect 2).



Figure L-10. Photograph taken on CHAT011 looking upstream from T6 (detailed transect 3).



Figure L-11. Photograph taken on CHAT011 looking downstream from T6 (detailed transect 3).



Figure L-12. Photograph taken on CHAT011 looking at the left bank from T6 (detailed transect 3).



Figure L-13. Photograph taken on CHAT011 looking at the right bank from T6 (detailed transect 3).

Table L-1. Land use/land cover characteristics for 2001, 2006, and 2011 for CHAT011. The data included in this table are from the National Land Cover Dataset (Fry et al. 2001; Homer et al. 2006; Homer et al. 2015).

NLCD Class	2001 percent of watershed	2006 percent of watershed	2011 percent of watershed
Open Water	0	0	0
Developed - Open[1]	13	18	15
Developed - Low[1]	17	22	23
Developed - Medium[1]	24	30	37
Developed - High[1]	5	5	5
Barren	0	0	0
Deciduous	27	22	18
Evergreen	13	4	1
Mixed Forest	0	0	0
Shrub	0	0	0
Grassland	0	0	0
Pasture	0	0	0
Cultivated	0	0	0
Woody Wetland	0	0	0
Herbaceous Wetland	0	0	0

[1] refers to the intensity or type of development.

Table L-2. Geomorphic channel units (GCU) observed in the area between transects at CHAT011. The data describe the percent coverage of each type of GCU [SD—Standard deviation].

Transect	(%) Riffle	(%) Run	(%) Glide	(%) Pool	(%) Step
1–2	100	0	0	0	0
2–3	100	0	0	0	0
3–4	100	0	0	0	0
4–5	100	0	0	0	0
5–6	0	100	0	0	0
6–7	0	100	0	0	0
7–8	20	80	0	0	0

Table L-2 (continued). Geomorphic channel units (GCU) observed in the area between transects at CHAT011. The data describe the percent coverage of each type of GCU [SD—Standard deviation].

Transect	(%) Riffle	(%) Run	(%) Glide	(%) Pool	(%) Step
8–9	0	0	0	100	0
9–10	0	0	0	100	0
10–11	0	0	0	100	0
Frequency	5	3	0	3	0
Max (%)	100	100	0	100	0
Mean (%)	42	28	0	30	0
Median (%)	10	0	0	0	0
SD (%)	50	45	0	48	0

There was no large woody debris (LWD) present at CHAT011.

Table L-3. Variability of canopy cover observed at CHAT011 [SD—Standard deviation; CV—Coefficient of variation].

Transect	Canopy Cover (%)
1	94
2	97
3	90
4	91
5	93
6	91
7	90
8	90
9	96
10	93
11	90
Min (%)	90
Max (%)	97
Mean (%)	92
Median (%)	91
SD (%)	3
CV	0.03

Table L-4. Average reach-scale bank characteristics at CHAT011. [L indicates left bank and R indicates right bank; SD—Standard deviation; CV—Coefficient of variation; m—meters].

Bank Characteristics	n (L)	n (R)	Min (L)	Min (R)	Max (L)	Max (R)	Mean (L)	Mean (R)	Median (L)	Median (R)	SD (L)	SD (R)	CV (L)	CV (R)
Bank Height[1] (m)	11	11	0.76	0.56	1.38	10.40	1.22	4.71	1.27	1.55	0.18	4.37	0.15	0.93
Bankfull Height[1,2] (m)	1	4	0.36	0.33	0.36	0.53	0.36	0.40	0.36	0.37	–	0.09	–	0.23
Channel-full Height[1,2] (m)	11	11	0.84	0.59	1.73	10.54	1.38	4.87	1.39	1.63	0.26	4.51	0.19	0.93
Water Depth at Base[3] (m)	11	11	-0.10	-0.15	0.18	0.05	-0.01	-0.04	-0.02	-0.03	0.08	0.07	–	–
Bank Undercut[2] (m)	5	2	0.05	0.05	0.42	0.17	0.17	0.11	0.16	0.11	0.15	0.08	0.90	0.77
Bank Angle (°)	11	11	12	8	99	89	64	54	76	57	31	30	0.48	0.56
Vegetation Cover (%)	11	11	5	10	80	80	37	45	40	40	25	23	0.68	0.50
Bank Stability[4]	11	11	At-Risk	At-Risk	Very Unstable	Very Unstable	Unstable	Unstable	Unstable	Unstable	1.99	2.39	0.15	0.21

[1] above thalweg.

[2] statistics are based on the transects where feature is present (# in parentheses).

[3] a negative number indicates base of bank is above the water surface.

[4] see Table 1 for explanation of scores.

Table L-5. Cross-sectional characteristics for detailed transect 1 at CHAT011 [m—meter].

Type	Area (m^2)	Perimeter (m)	Hydraulic Radius (m)	Width (m)	Depth (m)	Width/Depth
Bankfull	1.02	4.20	0.24	3.82	0.38	9.93
Channel-full	7.55	10.39	0.73	9.38	1.37	6.83
Bankfull and Channel–full Ratio	7.43	2.47	3.01	2.46	3.57	0.69

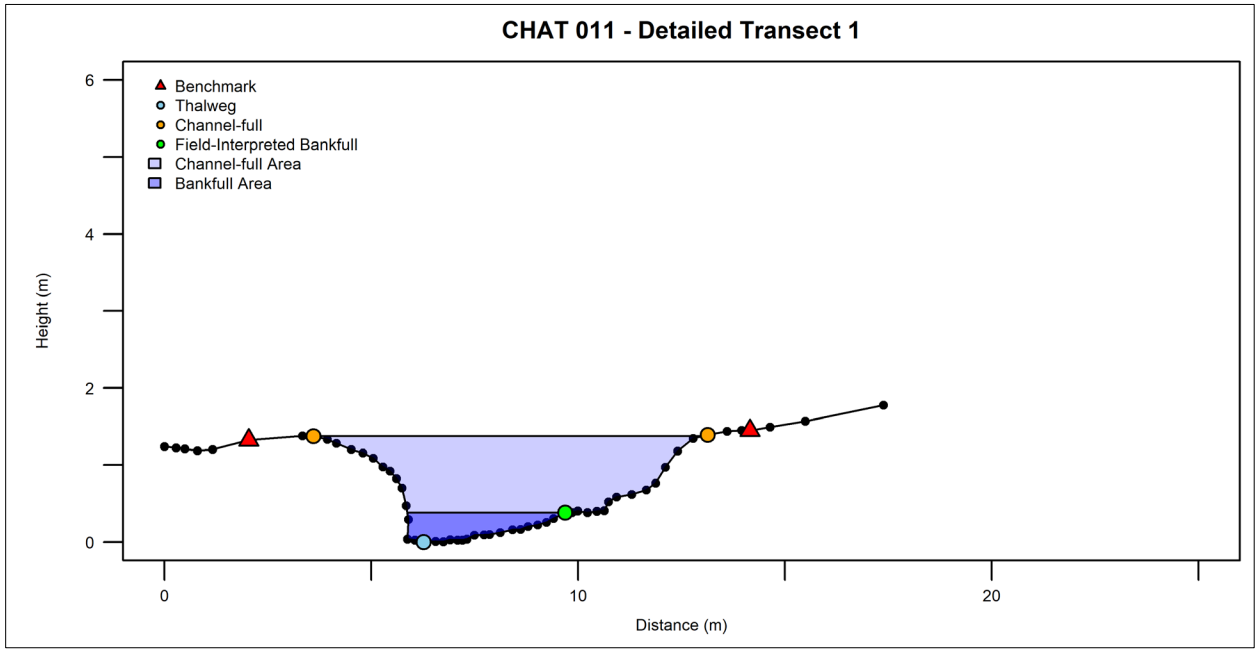


Figure L-14. Detailed transect 1 at CHAT011. The surveyed locations of the left and right benchmarks, channel-full bank-tops, and interpreted bankfull bank height are shown on the figure. Additionally, the channel-full (light blue) and bankfull (dark blue) cross-sectional areas are also included (channel-full cross-sectional area equals light blue plus dark blue).

Table L-6. Cross-sectional characteristics for detailed transect 2 at CHAT011 [m—meter].

Type	Area (m^2)	Perimeter (m)	Hydraulic Radius (m)	Width (m)	Depth (m)	Width/Depth
Bankfull	0.95	4.65	0.20	4.46	0.26	17.13
Channel-full	2.27	5.94	0.38	5.57	0.52	10.77
Bankfull and Channel–full Ratio	2.40	1.28	1.88	1.25	1.99	0.63

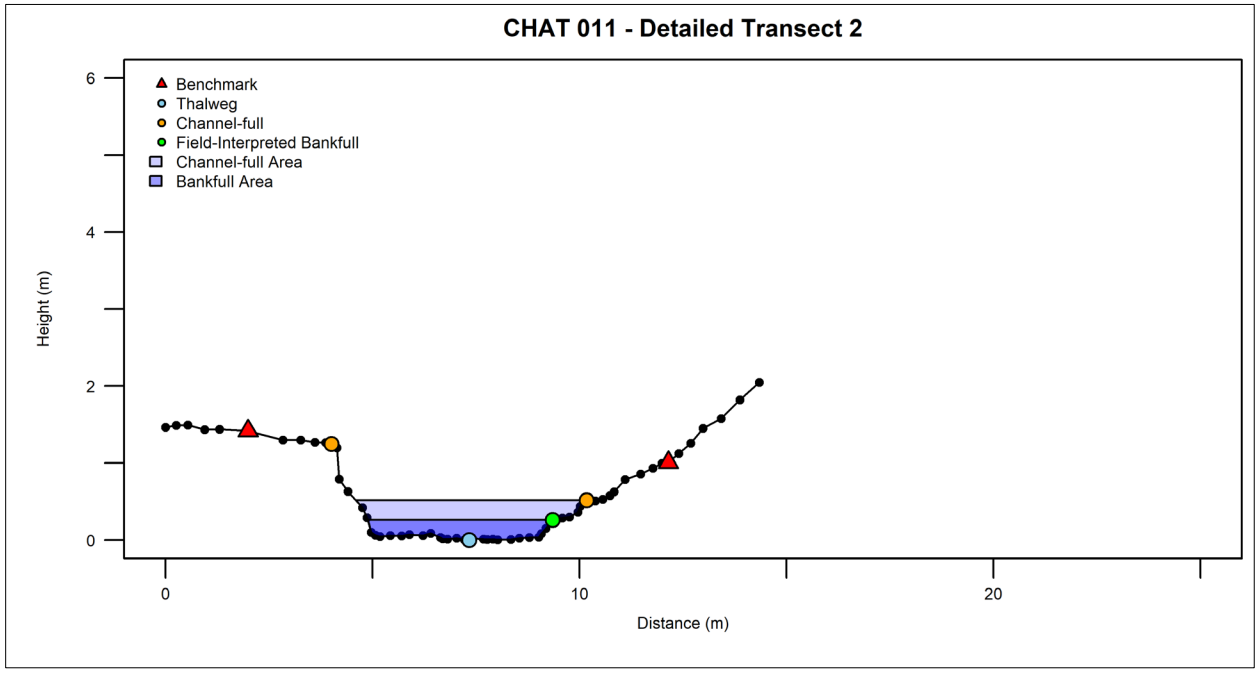


Figure L-15. Detailed transect 2 at CHAT011. The surveyed locations of the left and right benchmarks, channel-full bank-tops, and bankfull bank height are shown on the figure. Channel-full (light blue) and bankfull (dark blue) cross-sectional areas are also included (channel-full cross-sectional area equals light blue plus dark blue).

Table L-7. Cross-sectional characteristics for detailed transect 3 at CHAT011 [m—meter].

Type	Area (m^2)	Perimeter (m)	Hydraulic Radius (m)	Width (m)	Depth (m)	Width/Depth
Bankfull	0.60	4.65	0.13	4.46	0.20	22.21
Channel-full	5.06	8.49	0.60	7.69	0.98	7.87
Bankfull and Channel–full Ratio	8.39	1.83	4.60	1.72	4.87	0.35

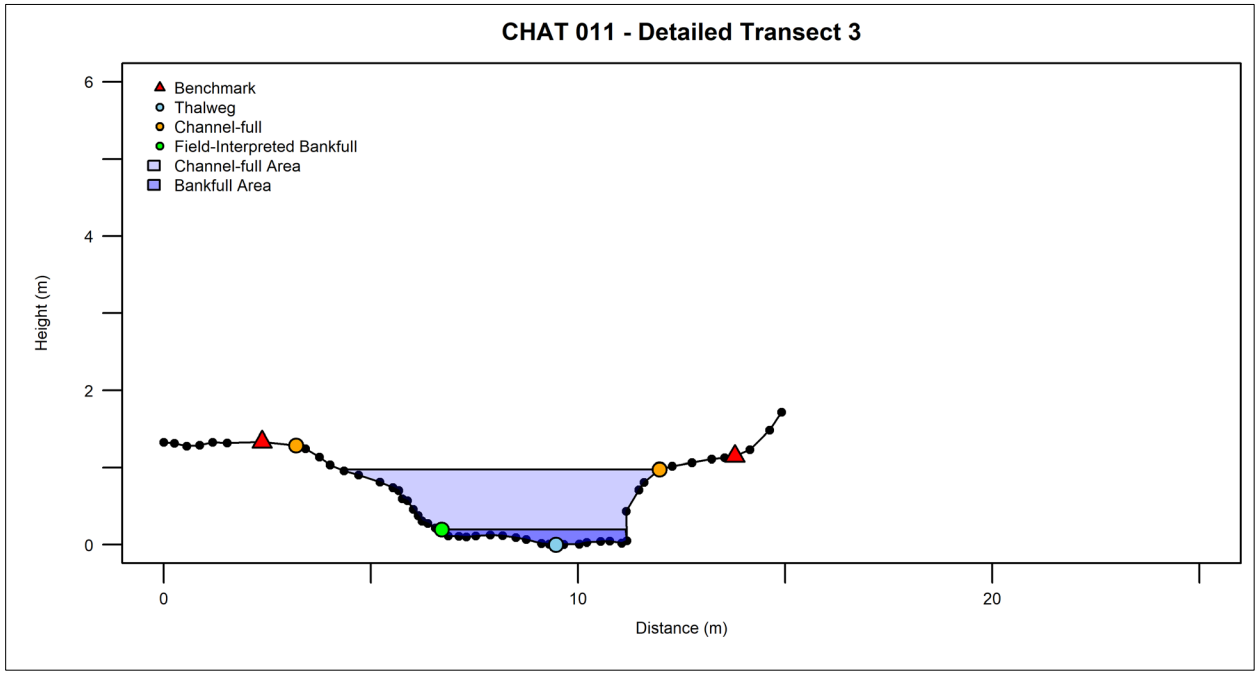


Figure L-16. Detailed transect 3 at CHAT011. The surveyed locations of the left and right benchmarks, channel-full bank-tops, and interpreted bankfull bank height are shown on the figure. Channel-full (light blue) and bankfull (dark blue) cross-sectional areas are also included (channel-full cross-sectional area equals light blue plus dark blue).

Literature Cited

Fry, J. A., G. Xian, S. Jin, J. A. Dewitz, C. G. Homer, L. Yang, C. A. Barnes, N. D. Herold, J. D. Wickham. 2006. Completion of the 2006 National Land Cover Database for the conterminous United States: Photogrammetric Engineering and Remote Sensing, v. 77, no. 9, p. 858–864.

Homer, C. G., J. A. Dewitz, J. A. Fry, M. J. Coan, S. M. Hossain, L. Nazmul, R. Charles, N. Herold, A. McKerrow, J. N Van Driel, J. Wickham. 2001. Completion of the 2001 National Land Cover Database for the conterminous United States: Photogrammetric Engineering and Remote Sensing, v. 73, no. 4, p. 337–341.

Homer, C. G., J. A. Dewitz, L. Yang, S. Jin, P. Danielson, G. Xian, J. Coulston, N. D. Herold, J. D. Wickham, and K. Megown. 2015. Completion of the 2011 national land cover database for the conterminous United States—representing a decade of land cover change information. Photogrammetric Engineering and Remote Sensing. 81:345–354.

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Appendix M. Survey Results for CHAT014

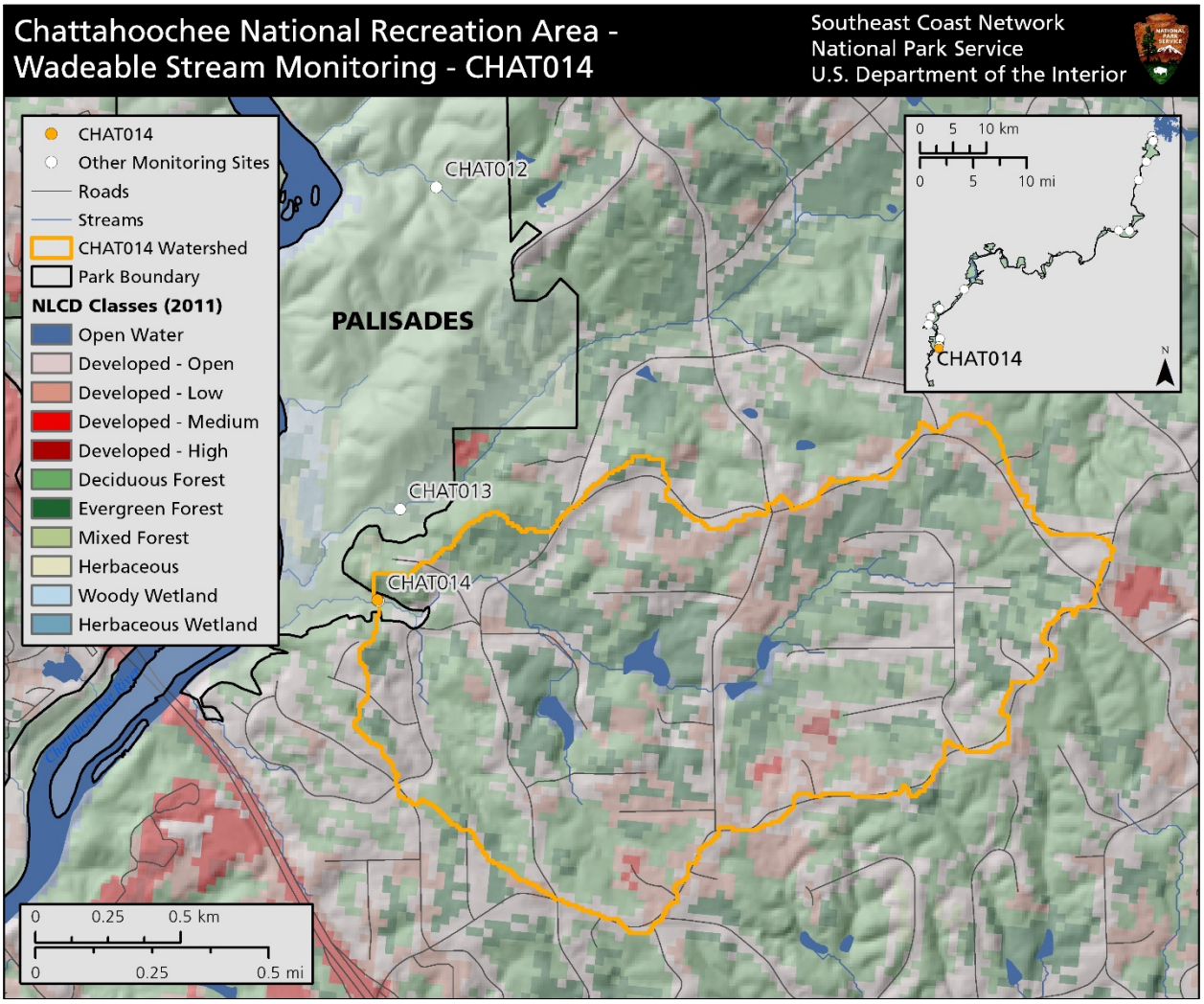


Figure M-1. Map showing the watershed draining to CHAT014 at Chattahoochee National Recreation Area. The land use/land cover (NLCD 2011, Homer et al. 2015), road network (USCB 2011), and perennial streams (derived from a 10-meter (32.8-feet) digital elevation model; data available from the U.S. Geological Survey) in the vicinity of the park are also shown.



Figure M-2. Photograph taken on CHAT014 looking upstream from T1 (detailed transect 1).



Figure M-3. Photograph taken on CHAT014 looking downstream from T1 (detailed transect 1).



Figure M-4. Photograph taken on CHAT014 looking at the left bank from T1 (detailed transect 1).



Figure M-5. Photograph taken on CHAT014 looking at the right bank from T1 (detailed transect 1).



Figure M-6. Photograph taken on CHAT014 looking upstream from T6 (detailed transect 2).



Figure M-7. Photograph taken on CHAT014 looking downstream from T6 (detailed transect 2).



Figure M-8. Photograph taken on CHAT014 looking at the left bank from T6 (detailed transect 2).



Figure M-9. Photograph taken on CHAT014 looking at the right bank from T6 (detailed transect 2).



Figure M-10. Photograph taken on CHAT014 looking upstream from T10 (detailed transect 3).



Figure M-11. Photograph taken on CHAT014 looking downstream from T10 (detailed transect 3).



Figure M-12. Photograph taken on CHAT014 looking at the left bank from T10 (detailed transect 3).



Figure M-13. Photograph taken on CHAT014 looking at the right bank from T10 (detailed transect 3).

Table M-1. Land use/land cover characteristics for 2001, 2006, and 2011 for CHAT014. The data included in this table are from the National Land Cover Dataset (Fry et al. 2001; Homer et al. 2006; Homer et al. 2015).

NLCD Class	2001 percent of watershed	2006 percent of watershed	2011 percent of watershed
Open Water	1	1	1
Developed - Open[1]	32	32	33
Developed - Low[1]	13	13	13
Developed - Medium[1]	0	0	0
Developed - High[1]	0	0	0
Barren	0	0	0
Deciduous	30	30	29
Evergreen	23	23	22
Mixed Forest	0	0	0
Shrub	0	0	0
Grassland	0	0	0
Pasture	0	0	0
Cultivated	0	0	0
Woody Wetland	0	0	0
Herbaceous Wetland	0	0	0

[1] refers to the intensity or type of development.

Table M-2. Geomorphic channel units (GCU) observed in the area between transects at CHAT014. The data describe the percent coverage of each type of GCU. [SD—Standard deviation].

Transect	(%) Riffle	(%) Run	(%) Glide	(%) Pool	(%) Step
1–2	0	0	0	100	0
2–3	0	0	0	100	0
3–4	0	0	0	100	0
4–5	0	0	0	100	0
5–6	10	0	0	90	0
6–7	33	0	0	67	0
7–8	0	0	0	100	0

Table M-2 (continued). Geomorphic channel units (GCU) observed in the area between transects at CHAT014. The data describe the percent coverage of each type of GCU. [SD—Standard deviation].

Transect	(%) Riffle	(%) Run	(%) Glide	(%) Pool	(%) Step
8–9	0	0	0	100	0
9–10	0	100	0	0	0
10–11	40	60	0	0	0
Frequency	3	2	0	8	0
Max (%)	40	100	0	100	0
Mean (%)	8	16	0	76	0
Median (%)	0	0	0	100	0
SD (%)	15	35	0	41	0

Table M-3. Characteristics of the large woody debris (LWD) observed at CHAT014 [m—meter].

LWD ID	Length (m)	Diameter (m)	Volume (m^3)	Transect Interval	Function	Position
1	4.95	0.15	0.09	8	Jam, Organic trap	Jam
2	3.75	0.30	0.27	8	Organic trap	Bridge

Table M-4. Variability of canopy cover observed at CHAT014 [SD—Standard deviation; CV—Coefficient of variation].

Transect	Canopy Cover (%)
1	96
2	99
3	94
4	88
5	91
6	88
7	96
8	97
9	99
10	96
11	93
Min (%)	88
Max (%)	99
Mean (%)	94
Median (%)	96
SD (%)	4
CV	0.04

Table M-5. Average reach-scale bank characteristics at CHAT014. [L indicates left bank and R indicates right bank; SD—Standard deviation; CV—Coefficient of variation; m—meters].

Bank Characteristics	n (L)	n (R)	Min (L)	Min (R)	Max (L)	Max (R)	Mean (L)	Mean (R)	Median (L)	Median (R)	SD (L)	SD (R)	CV (L)	CV (R)
Bank Height[1] (m)	11	11	0.59	0.56	1.02	1.07	0.87	0.90	0.90	0.95	0.14	0.16	0.16	0.18
Bankfull Height[1,2] (m)	2	1	0.53	0.43	0.65	0.43	0.59	0.43	0.59	0.43	0.08	–	0.14	–
Channel-full Height[1,2] (m)	11	11	0.77	0.61	1.42	1.47	1.12	1.15	1.16	1.22	0.17	0.28	0.16	0.25
Water Depth at Base[3] (m)	11	11	-0.16	-0.18	0.14	0.18	-0.04	0.02	-0.08	0.04	0.10	0.10	–	–
Bank Undercut[2] (m)	3	6	0.05	0.06	0.14	0.27	0.10	0.17	0.11	0.20	0.05	0.08	0.46	0.47
Bank Angle (°)	11	11	9	33	91	90	50	69	47	80	33	21	0.66	0.30
Vegetation Cover (%)	11	11	0	5	60	70	20	39	15	50	17	24	0.87	0.63
Bank Stability[4]	11	11	Unstable	At-Risk	Very Unstable	Very Unstable	Unstable	Unstable	Unstable	Unstable	1.37	1.95	0.09	0.15

[1] above thalweg.

[2] statistics are based on the transects where feature is present (# in parentheses)

[3] a negative number indicates base of bank is above the water surface.

[4] see Table 1 for explanation in scores.

Table M-6. Cross-sectional characteristics for detailed transect 1 at CHAT014 [m—meter].

Type	Area (m^2)	Perimeter (m)	Hydraulic Radius (m)	Width (m)	Depth (m)	Width/Depth
Bankfull	1.07	3.80	0.28	3.39	0.53	6.40
Channel-full	3.60	6.40	0.56	5.63	1.12	5.03
Bankfull and Channel–full Ratio	3.37	1.69	2.00	1.66	2.11	0.79

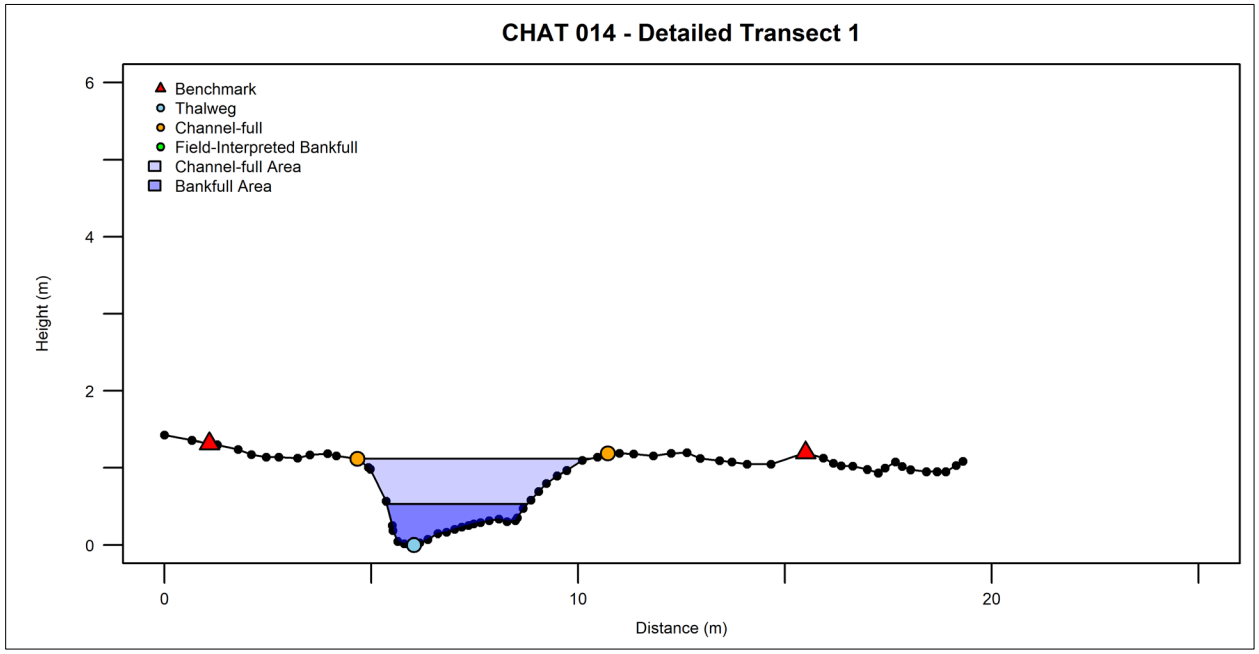


Figure M-14. Detailed transect 1 at CHAT014. The surveyed locations of the left and right benchmarks, channel-full bank-tops, and interpreted bankfull bank height are shown on the figure. Additionally, the channel-full (light blue) and bankfull (dark blue) cross-sectional areas are also included (channel-full cross-sectional area equals light blue plus dark blue).

Table M-7. Cross-sectional characteristics for detailed transect 2 at CHAT014 [m—meter].

Type	Area (m^2)	Perimeter (m)	Hydraulic Radius (m)	Width (m)	Depth (m)	Width/Depth
Bankfull	1.28	3.89	0.33	3.60	0.48	7.46
Channel-full	2.81	5.54	0.51	4.94	0.85	5.80
Bankfull and Channel–full Ratio	2.20	1.42	1.54	1.37	1.77	0.78

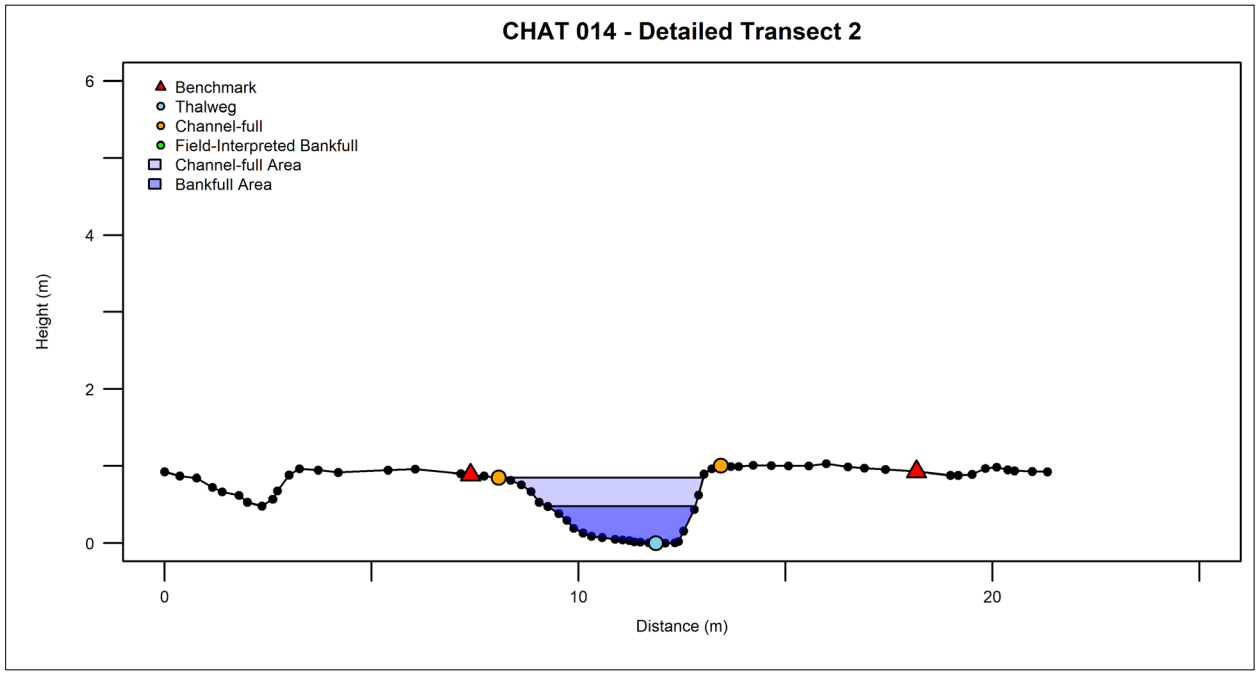


Figure M-15. Detailed transect 2 at CHAT014. The surveyed locations of the left and right benchmarks, channel-full bank-tops, and bankfull bank height are shown on the figure. Channel-full (light blue) and bankfull (dark blue) cross-sectional areas are also included (channel-full cross-sectional area equals light blue plus dark blue).

Table M-8. Cross-sectional characteristics for detailed transect 3 at CHAT014 [m—meter].

Type	Area (m^2)	Perimeter (m)	Hydraulic Radius (m)	Width (m)	Depth (m)	Width/Depth
Bankfull	1.11	4.87	0.23	4.76	0.40	11.95
Channel-full	2.11	6.76	0.31	6.61	0.57	11.56
Bankfull and Channel–full Ratio	1.90	1.39	1.37	1.39	1.44	0.97

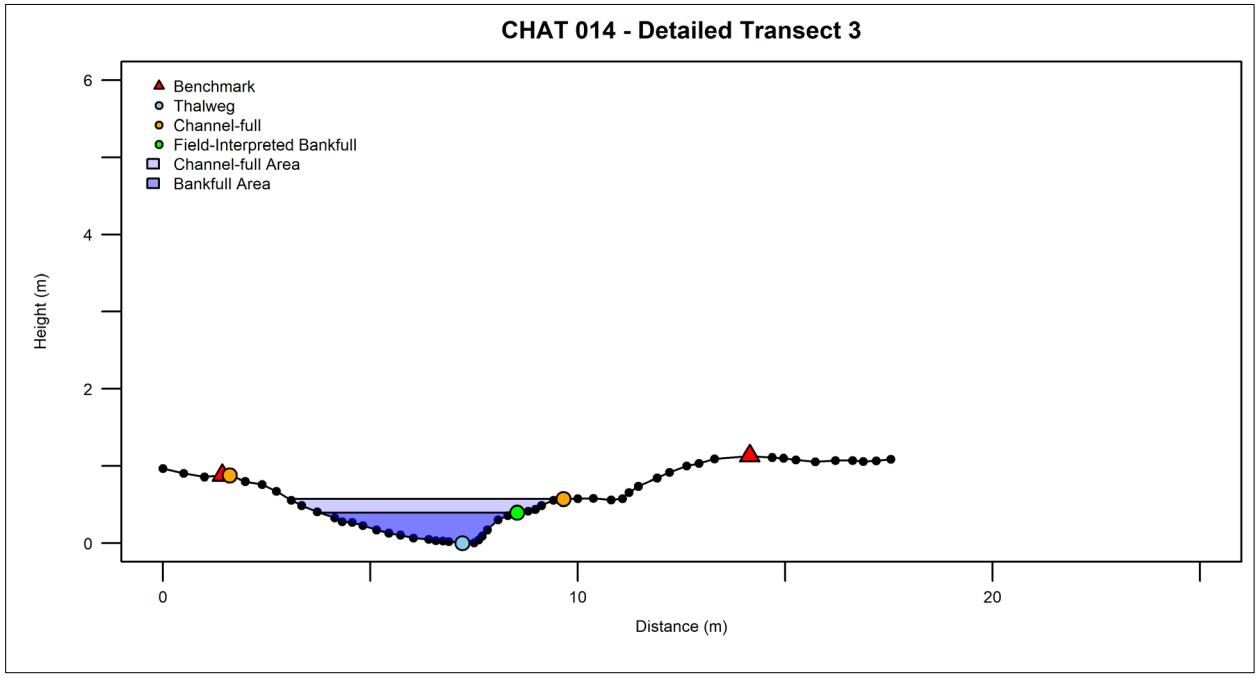


Figure M-16. Detailed transect 3 at CHAT014. The surveyed locations of the left and right benchmarks, channel-full bank-tops, and interpreted bankfull bank height are shown on the figure. Channel-full (light blue) and bankfull (dark blue) cross-sectional areas are also included (channel-full cross-sectional area equals light blue plus dark blue).

Literature Cited

Fry, J. A., G. Xian, S. Jin, J. A. Dewitz, C. G. Homer, L. Yang, C. A. Barnes, N. D. Herold, J. D. Wickham. 2006. Completion of the 2006 National Land Cover Database for the conterminous United States: Photogrammetric Engineering and Remote Sensing, v. 77, no. 9, p. 858–864.

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United States Census Bureau (USCB). 2011. TIGER/Line Shapefiles-all roads, county-based. Available at https://www.census.gov/geographies/mapping-files/time-series/geo/tiger-line-file.2011.html (last accessed September 2019).

Appendix N. Survey Results for CHAT001

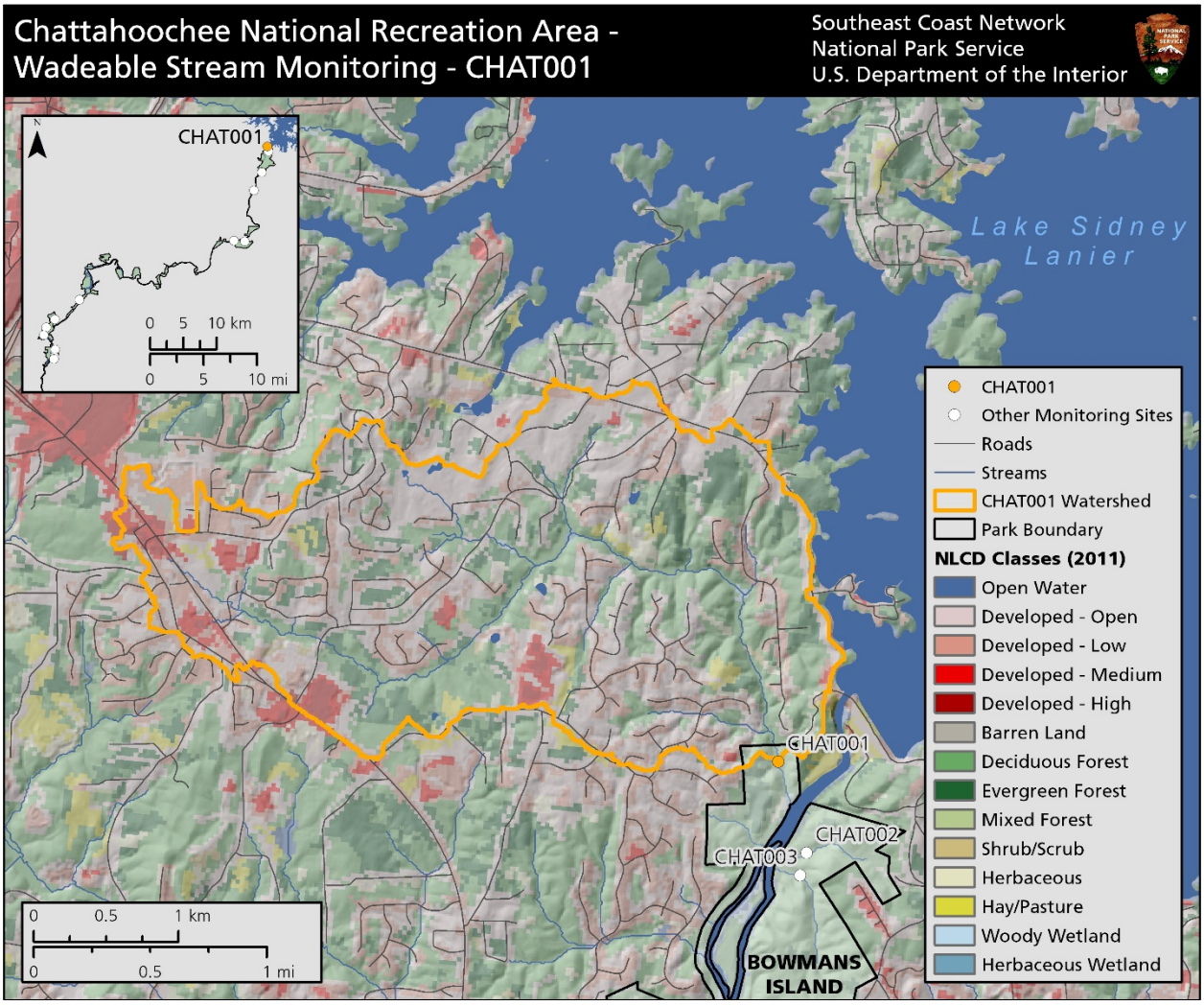


Figure N-1. Map showing the watershed draining to CHAT001 at Chattahoochee National Recreation Area. The land use/land cover (NLCD 2011, Homer et al. 2015), road network (USCB 2011), and perennial streams (derived from a 10 m digital elevation model; data available from the U.S. Geological Survey) in the vicinity of the park are also shown.



Figure N-2. Photograph taken on CHAT001 looking upstream from T2 (detailed transect 1).



Figure N-3. Photograph taken on CHAT001 looking downstream from T2 (detailed transect 1).



Figure N-4. Photograph taken on CHAT001 looking at the left bank from T2 (detailed transect 1).



Figure N-5. Photograph taken on CHAT001 looking at the right bank from T2 (detailed transect 1).



Figure N-6. Photograph taken on CHAT001 looking upstream from T6 (detailed transect 2).



Figure N-7. Photograph taken on CHAT001 looking downstream from T6 (detailed transect 2).



Figure N-8. Photograph taken on CHAT001 looking at the left bank from T6 (detailed transect 2).



Figure N-9. Photograph taken on CHAT001 looking at the right bank from T6 (detailed transect 2).



Figure N-10. Photograph taken on CHAT001 looking upstream from T8 (detailed transect 3).



Figure N-11. Photograph taken on CHAT001 looking downstream from T8 (detailed transect 3).



Figure N-12. Photograph taken on CHAT001 looking at the left bank from T8 (detailed transect 3).



Figure N-13. Photograph taken on CHAT001 looking at the right bank from T8 (detailed transect 3).

Table N-1. Land use/land cover characteristics for 2001, 2006, and 2011 for CHAT001. The data included in this table are from the National Land Cover Dataset (Fry et al. 2001; Homer et al. 2006; Homer et al. 2015).

NLCD Class	2001 percent of watershed	2006 percent of watershed	2011 percent of watershed
Open Water	0	0	0
Developed - Open[1]	31	35	36
Developed - Low[1]	15	17	18
Developed - Medium[1]	1	1	3
Developed - High[1]	0	1	1
Barren	0	0	0
Deciduous	32	29	27
Evergreen	12	11	9
Mixed Forest	0	0	0
Shrub	0	0	0
Grassland	4	2	2
Pasture	5	4	2
Cultivated	0	0	0
Woody Wetland	0	0	0
Herbaceous Wetland	0	0	0

[1] refers to the intensity or type of development.

Table N-2. Geomorphic channel units (GCU) observed in the area between transects at CHAT001. The data describe the percent coverage of each type of GCU [SD—Standard deviation].

Transect	(%) Riffle	(%) Run	(%) Glide	(%) Pool	(%) Step
1–2	10	25	0	65	0
2–3	25	0	0	75	0
3–4	100	0	0	0	0
4–5	30	70	0	0	0
5–6	50	30	0	20	0
6–7	20	30	0	50	0
7–8	0	0	0	100	0

Table N-2 (continued). Geomorphic channel units (GCU) observed in the area between transects at CHAT001. The data describe the percent coverage of each type of GCU [SD—Standard deviation].

Transect	(%) Riffle	(%) Run	(%) Glide	(%) Pool	(%) Step
8–9	0	0	0	100	0
9–10	0	10	0	90	0
10–11	0	0	75	25	0
Frequency	6	5	1	8	0
Max (%)	100	70	75	100	0
Mean (%)	24	17	8	53	0
Median (%)	15	5	0	58	0
SD (%)	32	23	24	39	0

Table N-3. Characteristics of the large woody debris (LWD) observed at CHAT001 [m—meter].

LWD ID	Length (m)	Diameter (m)	Volume (m^3)	Transect Interval	Function	Position
1	3.64	0.13	0.05	11	Organic trap, Sediment trap	Buried
2	3.97	0.12	0.04	10	Organic trap, Jam	Jam
3	5.18	0.12	0.06	10	Jam, Sediment trap, Organic trap, Bank Protection	Jam
4	10.95	0.20	0.34	9	Organic trap	Bridge
5	9.15	0.12	0.10	8	Jam, Organic trap	Bridge
6	8.09	0.16	0.16	8	Bank Protection, Jam	Jam
7	8.50	0.12	0.10	7	Jam, Bank Protection	Jam
8	10.42	0.30	0.74	7	Jam, Bank Protection, Organic trap	Jam
9	8.16	0.19	0.23	7	Jam, Bank Protection, Organic trap	Jam
10	3.87	0.19	0.11	5	Bank Protection	Buried
11	2.51	0.16	0.05	3	Jam, Organic trap	Jam
12	13.17	0.17	0.30	3	Jam, Organic trap, Bank Protection	Jam

Table N-3 (continued). Characteristics of the large woody debris (LWD) observed at CHAT001 [m—meter].

LWD ID	Length (m)	Diameter (m)	Volume (m^3)	Transect Interval	Function	Position
13	4.86	0.16	0.10	2	Bank Protection	Buried
14	4.00	0.43	0.58	2	Jam, Organic trap, Sediment trap, Pool formation	Bridge
15	5.67	0.22	0.22	2	Jam, Organic trap	Buried
16	3.44	0.14	0.05	1	Organic trap	Buried

Table N-4. Variability of canopy cover observed at CHAT001 [SD—Standard deviation; CV—Coefficient of variation].

Transect	Canopy Cover (%)
1	63
2	43
3	34
4	60
5	82
6	81
7	78
8	99
9	85
10	91
11	97
Min (%)	34
Max (%)	99
Mean (%)	74
Median (%)	81
SD (%)	21
CV	0.29

Table N-5. Average reach-scale bank characteristics at CHAT001. [L indicates left bank and R indicates right bank; SD—Standard deviation; CV—Coefficient of variation; m—meters].

Bank Characteristics	n (L)	n (R)	Min (L)	Min (R)	Max (L)	Max (R)	Mean (L)	Mean (R)	Median (L)	Median (R)	SD (L)	SD (R)	CV (L)	CV (R)
Bank Height[1] (m)	11	11	0.79	0.61	2.60	2.57	1.82	1.57	1.87	1.68	0.71	0.68	0.39	0.43
Bankfull Height[1,2] (m)	1	5	0.89	0.57	0.89	1.34	0.89	0.94	0.89	0.97	–	0.29	–	0.31
Channel-full Height[1,2] (m)	11	11	0.99	0.74	3.08	3.15	2.21	1.96	2.56	1.98	0.71	0.81	0.32	0.41
Water Depth at Base[3] (m)	11	11	-0.10	-0.23	0.28	0.06	-0.02	-0.08	-0.08	-0.08	0.13	0.07	–	–
Bank Undercut[2] (m)	2	3	0.23	0.20	0.26	1.62	0.25	0.83	0.25	0.66	0.02	0.72	0.09	0.88
Bank Angle (°)	11	11	14	28	94	118	41	54	30	41	27	28	0.66	0.52
Vegetation Cover (%)	11	11	5	15	90	100	49	58	40	70	30	33	0.62	0.57
Bank Stability[4]	11	11	At-Risk	Stable	Very Unstable	Very Unstable	Unstable	Unstable	Unstable	Unstable	2.04	2.51	0.16	0.20

[1] above thalweg.

[2] statistics are based on the transects where feature is present (# in parentheses)

[3] a negative number indicates base of bank is above the water surface.

[4] see Table 1 for explanation in scores.

Table N-6. Cross-sectional characteristics for detailed transect 1 at CHAT001 [m—meter].

Type	Area (m^2)	Perimeter (m)	Hydraulic Radius (m)	Width (m)	Depth (m)	Width/Depth
Bankfull	4.03	8.10	0.50	7.74	0.72	10.68
Channel-full	9.15	13.07	0.70	12.23	1.21	10.07
Bankfull and Channel–full Ratio	2.27	1.61	1.41	1.58	1.68	0.94

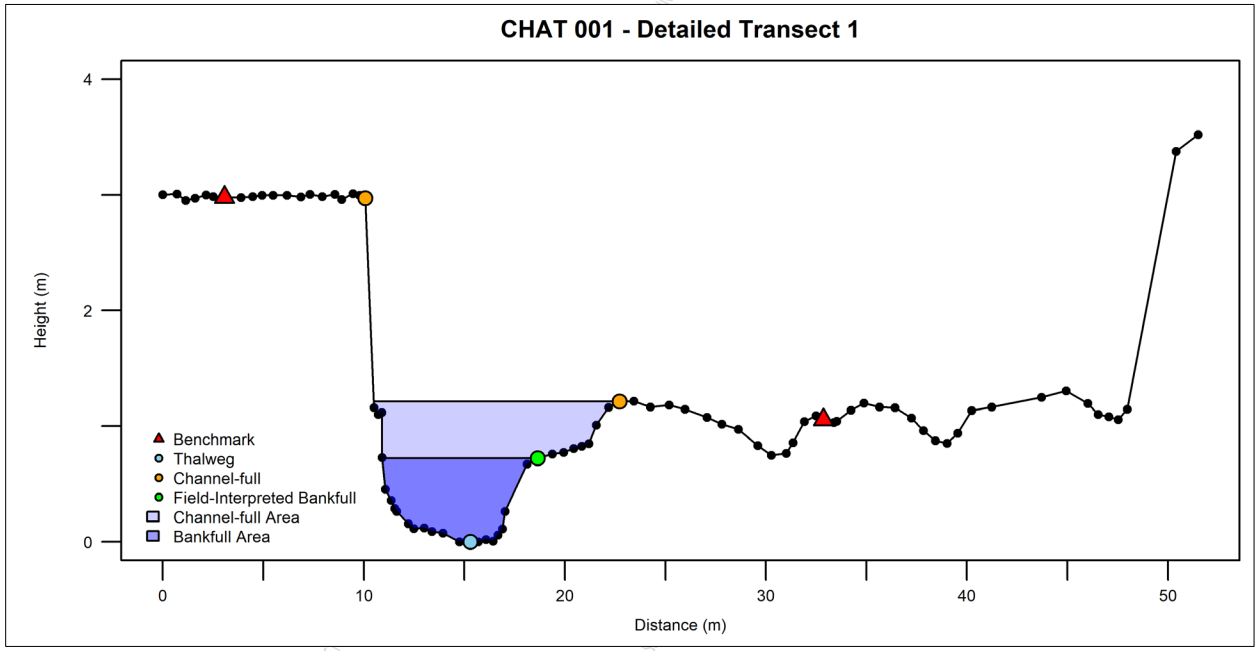


Figure N-14. Detailed transect 1 at CHAT001. The surveyed locations of the left and right benchmarks, channel-full bank-tops, and interpreted bankfull bank height are shown on the figure. Additionally, the channel-full (light blue) and bankfull (dark blue) cross-sectional areas are also included (channel-full cross-sectional area equals light blue plus dark blue).

Table N-7. Cross-sectional characteristics for detailed transect 2 at CHAT001 [m—meter].

Type	Area (m^2)	Perimeter (m)	Hydraulic Radius (m)	Width (m)	Depth (m)	Width/Depth
Bankfull	9.60	17.94	0.53	17.03	0.94	18.21
Channel-full	9.29	17.71	0.52	16.81	0.92	18.33
Bankfull and Channel–full Ratio	0.97	0.99	0.98	0.99	0.98	1.01

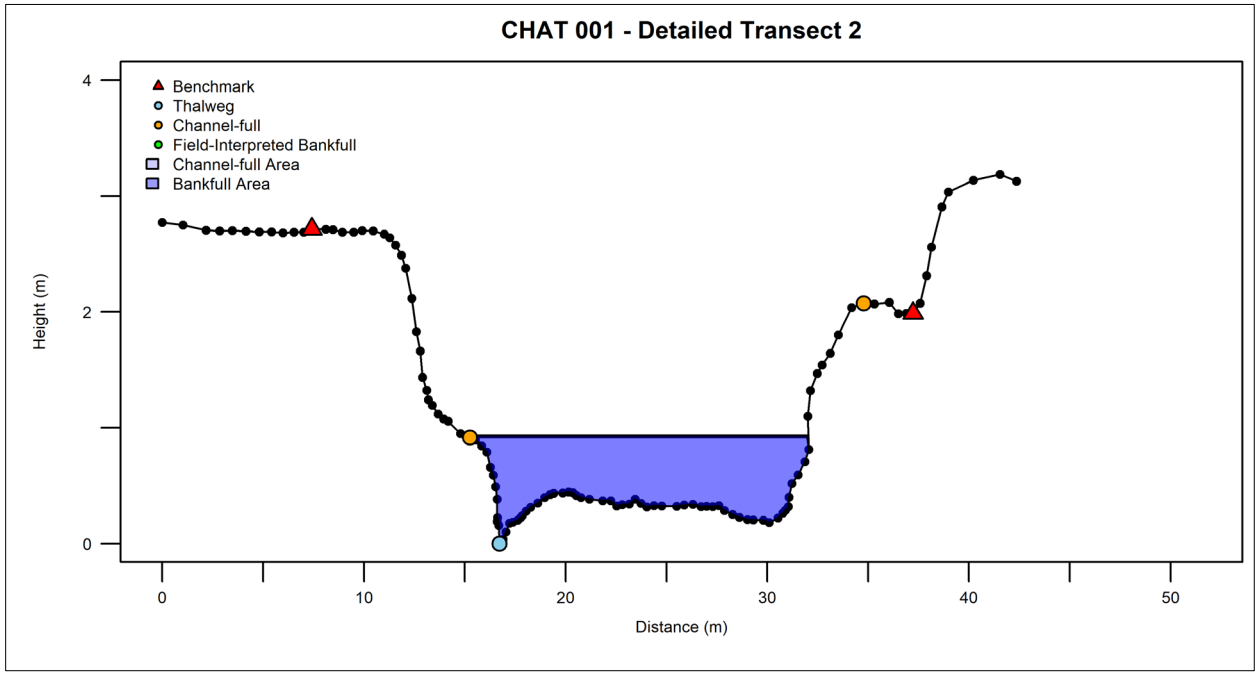


Figure N-15. Detailed transect 2 at CHAT001. The surveyed locations of the left and right benchmarks, channel-full bank-tops, and bankfull bank height are shown on the figure. Channel-full (light blue) and bankfull (dark blue) cross-sectional areas are also included (channel-full cross-sectional area equals light blue plus dark blue).

Table N-8. Cross-sectional characteristics for detailed transect 3 at CHAT001 [m—meter].

Type	Area (m^2)	Perimeter (m)	Hydraulic Radius (m)	Width (m)	Depth (m)	Width/Depth
Bankfull	3.97	10.13	0.39	9.74	0.71	13.70
Channel-full	41.40	24.42	1.70	22.13	2.57	8.62
Bankfull and Channel–full Ratio	10.42	2.41	4.32	2.27	3.61	0.63

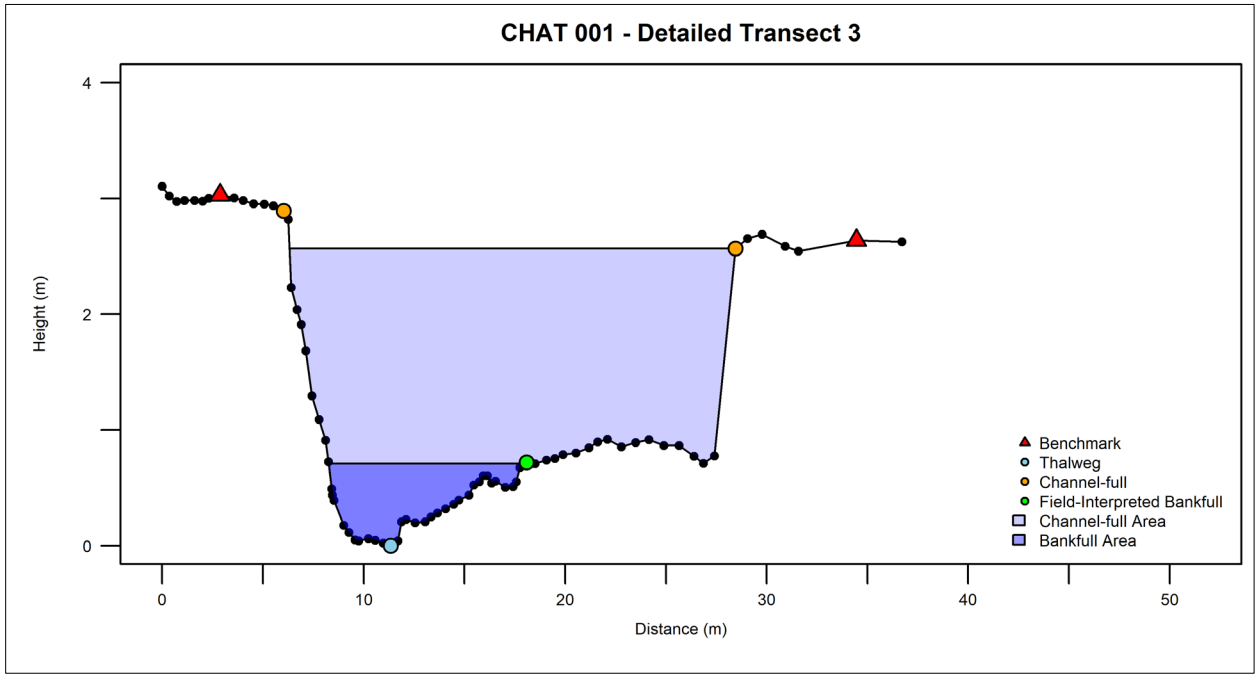


Figure N-16. Detailed transect 3 at CHAT001. The surveyed locations of the left and right benchmarks, channel-full bank-tops, and interpreted bankfull bank height are shown on the figure. Channel-full (light blue) and bankfull (dark blue) cross-sectional areas are also included (channel-full cross-sectional area equals light blue plus dark blue).

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Fry, J. A., G. Xian, S. Jin, J. A. Dewitz, C. G. Homer, L. Yang, C. A. Barnes, N. D. Herold, J. D. Wickham. 2006. Completion of the 2006 National Land Cover Database for the conterminous United States: Photogrammetric Engineering and Remote Sensing, v. 77, no. 9, p. 858–864.

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Homer, C. G., J. A. Dewitz, L. Yang, S. Jin, P. Danielson, G. Xian, J. Coulston, N. D. Herold, J. D. Wickham, and K. Megown. 2015. Completion of the 2011 national land cover database for the conterminous United States—representing a decade of land cover change information. Photogrammetric Engineering and Remote Sensing. 81:345–354.

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Appendix O. Survey Results for CHAT013

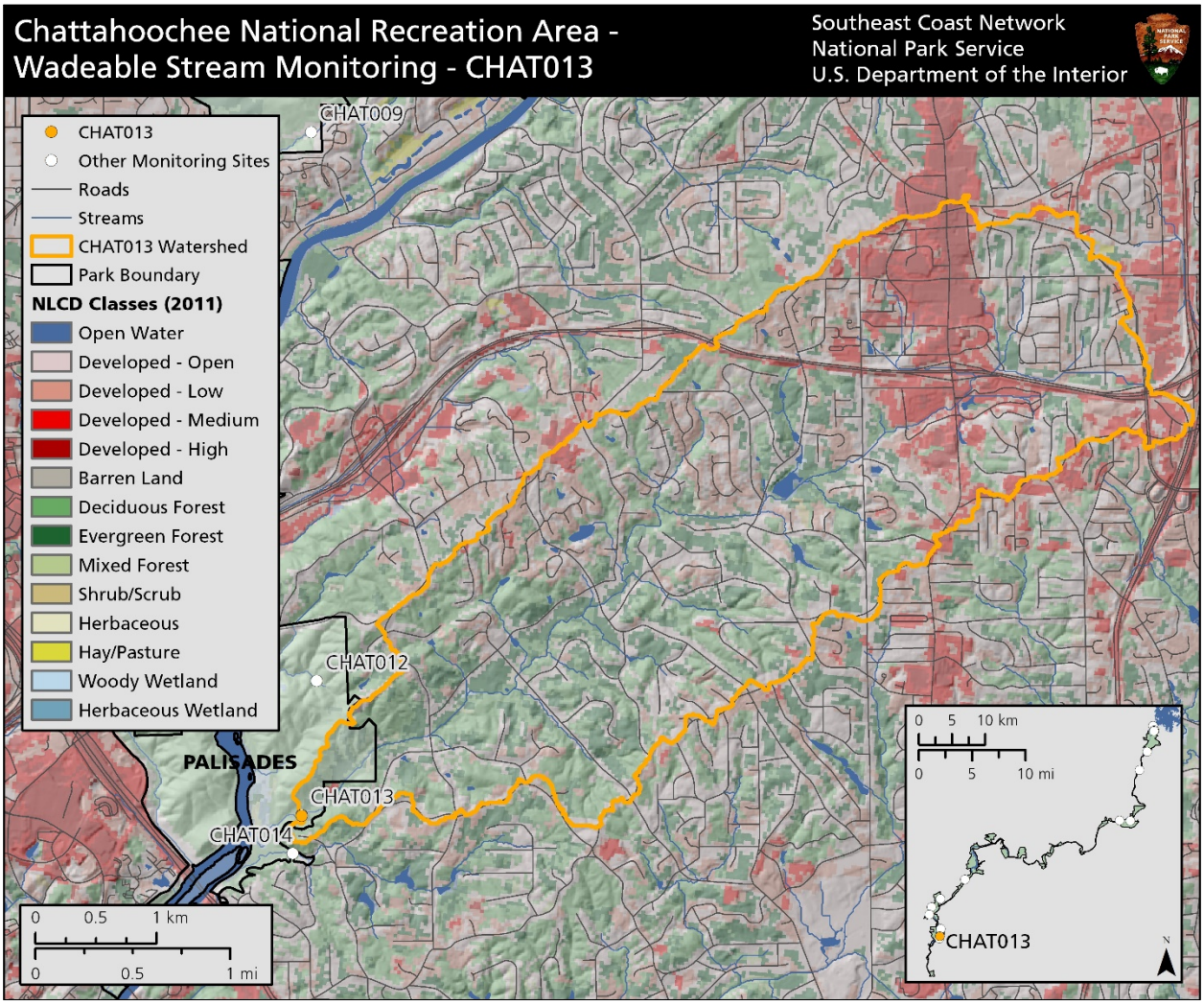


Figure O-1. Map showing the watershed draining to CHAT013 at Chattahoochee National Recreation Area. The land use/land cover (NLCD 2011; Homer et al. 2015), road network (USCB 2011), and perennial streams (derived from a 10-meter [32.8-feet] digital elevation model; data available from the U.S. Geological Survey) in the vicinity of the park are also shown.



Figure O-2. Photograph taken on CHAT013 looking upstream from T3 (detailed transect 1).



Figure O-3. Photograph taken on CHAT013 looking downstream from T3 (detailed transect 1).



Figure O-4. Photograph taken on CHAT013 looking at the left bank from T3 (detailed transect 1).



Figure O-5. Photograph taken on CHAT013 looking at the right bank from T3 (detailed transect 1).



Figure O-6. Photograph taken on CHAT013 looking upstream from T6 (detailed transect 2).



Figure O-7. Photograph taken on CHAT013 looking downstream from T6 (detailed transect 2).



Figure O-8. Photograph taken on CHAT013 looking at the left bank from T6 (detailed transect 2).



Figure O-9. Photograph taken on CHAT013 looking at the right bank from T6 (detailed transect 2).



Figure O-10. Photograph taken on CHAT013 looking upstream from T11 (detailed transect 3).



Figure O-11. Photograph taken on CHAT013 looking downstream from T11 (detailed transect 3).



Figure O-12. Photograph taken on CHAT013 looking at the left bank from T11 (detailed transect 3).



Figure O-13. Photograph taken on CHAT013 looking at the right bank from T11 (detailed transect 3).

Table O-1. Land use/land cover characteristics for 2001, 2006, and 2011 for CHAT013. The data included in this table are from the National Land Cover Dataset (Fry et al. 2001; Homer et al. 2006; Homer et al. 2015).

NLCD Class	2001 percent of watershed	2006 percent of watershed	2011 percent of watershed
Open Water	0	0	0
Developed - Open[1]	31	31	30
Developed - Low[1]	18	18	18
Developed - Medium[1]	7	7	8
Developed - High[1]	3	3	4
Barren	0	0	0
Deciduous	25	25	25
Evergreen	15	15	15
Mixed Forest	0	0	0
Shrub	0	0	0
Grassland	0	0	0
Pasture	0	0	0
Cultivated	0	0	0
Woody Wetland	0	0	0
Herbaceous Wetland	0	0	0

[1] refers to the intensity or type of development.

Table O-2. Geomorphic channel units (GCU) observed in the area between transects at CHAT013. The data describe the percent coverage of each type of GCU [SD—Standard deviation].

Transect	(%) Riffle	(%) Run	(%) Glide	(%) Pool	(%) Step
1–2	50	10	0	40	0
2–3	60	0	0	40	0
3–4	70	15	0	15	0
4–5	25	10	60	5	0
5–6	85	0	0	15	0
6–7	60	0	0	40	0
7–8	5	0	0	95	0

Table O-2 (continued). Geomorphic channel units (GCU) observed in the area between transects at CHAT013. The data describe the percent coverage of each type of GCU [SD—Standard deviation].

Transect	(%) Riffle	(%) Run	(%) Glide	(%) Pool	(%) Step
8–9	40	0	0	60	0
9–10	20	0	0	20	60
10–11	40	0	0	60	0
Frequency	10	3	1	10	1
Max (%)	85	15	60	95	60
Mean (%)	46	4	6	39	6
Median (%)	45	0	0	40	0
SD (%)	24	6	19	27	19

Table O-3. Characteristics of the large woody debris (LWD) observed at CHAT013 [m—meter].

LWD ID	Length (m)	Diameter (m)	Volume (m^3)	Transect Interval	Function	Position
1	7.17	0.21	0.25	2	Bank Protection, Pool formation, Sediment trap	Buried
2	4.37	0.10	0.03	3	Organic trap	Buried
3	1.13	0.23	0.05	3	Bank Protection	Buried
4	3.54	0.25	0.17	4	Bank Protection, Organic trap	Buried
5	1.15	0.29	0.08	4	Bank Protection	Buried
6	2.73	0.15	0.05	4	Bank Protection, Organic trap	Buried
7	2.03	0.11	0.02	4	Bank Protection, Organic trap	Buried
8	1.84	0.11	0.02	4	None	Free
9	2.03	0.19	0.06	5	Organic trap, Sediment trap	Free
10	2.94	0.14	0.05	6	None	Buried
11	1.64	0.22	0.06	6	Organic trap, Sediment trap	Buried
12	2.94	0.12	0.03	7	None	Buried

Table O-3 (continued). Characteristics of the large woody debris (LWD) observed at CHAT013 [m—meter].

LWD ID	Length (m)	Diameter (m)	Volume (m^3)	Transect Interval	Function	Position
13	4.93	0.46	0.82	10	Organic trap, Sediment trap, Pool formation	Step
14	3.63	0.23	0.15	10	Organic trap, Sediment trap, Pool formation	Step
15	3.42	0.28	0.21	10	Sediment trap, Bank Protection	Buried
16	1.06	0.10	0.01	10	None	Buried
17	1.07	0.43	0.16	10	Bank Protection, Sediment trap	Buried
18	5.21	0.33	0.45	10	Sediment trap, Pool formation	Buried, step
19	4.55	0.19	0.13	10	Pool formation, Sediment trap	Buried, step
20	4.26	0.44	0.65	10	Pool formation, Organic trap	Ramp
21	1.61	0.10	0.01	10	None	Buried
22	1.16	0.18	0.03	10	None	Buried
23	2.20	0.10	0.02	10	None	Buried
24	2.63	0.22	0.10	10	Bank Protection	Buried
25	2.21	0.13	0.03	10	Bank Protection, Sediment trap	Buried
26	1.56	0.15	0.03	10	Sediment trap	Buried
27	4.31	0.27	0.25	10	Pool formation, Sediment trap	Buried
28	1.91	0.11	0.02	10	Jam	Jam
29	4.82	0.32	0.39	11	None	Buried
30	4.21	0.25	0.21	11	Jam	Jam

Table O-4. Variability of canopy cover observed at CHAT013 [SD—Standard deviation; CV—Coefficient of variation].

Transect	Canopy Cover (%)
1	84
2	93
3	91
4	82
5	79
6	82
7	87
8	91
9	88
10	79
11	75
Min (%)	75
Max (%)	93
Mean (%)	85
Median (%)	84
SD (%)	6
CV	0.07

Table O-5. Average reach-scale bank characteristics at CHAT013. [L indicates left bank and R indicates right bank; SD—Standard deviation; CV—Coefficient of variation; m—meters].

Bank Characteristics	n (L)	n (R)	Min (L)	Min (R)	Max (L)	Max (R)	Mean (L)	Mean (R)	Median (L)	Median (R)	SD (L)	SD (R)	CV (L)	CV (R)
Bank Height[1] (m)	11	11	1.50	1.88	2.41	2.59	2.07	2.13	2.15	2.08	0.25	0.23	0.12	0.11
Bankfull Height[1,2] (m)	2	1	0.47	1.19	0.55	1.19	0.51	1.19	0.51	1.19	0.06	–	0.11	–
Channel-full Height[1,2] (m)	11	11	1.96	2.07	2.99	2.86	2.34	2.40	2.33	2.32	0.31	0.28	0.13	0.12
Water Depth at Base[3] (m)	11	11	-0.24	-0.07	0.21	0.41	-0.06	0.05	-0.06	0.00	0.12	0.14	–	–
Bank Undercut[2] (m)	2	5	0.09	0.14	0.19	0.54	0.14	0.24	0.14	0.17	0.07	0.17	0.51	0.71
Bank Angle (°)	11	11	13	6	87	88	58	61	61	73	25	31	0.43	0.51
Vegetation Cover (%)	11	11	0	20	50	60	25	43	30	50	20	13	0.77	0.30
Bank Stability[4]	11	11	At-Risk	At-Risk	Very Unstable	Very Unstable	Unstable	Unstable	Unstable	Unstable	2.23	2.44	0.15	0.19

[1] above thalweg.

[2] statistics are based on the transects where feature is present (# in parentheses)

[3] a negative number indicates base of bank is above the water surface.

[4] see Table 1 for explanation in scores.

Table O-6. Cross-sectional characteristics for detailed transect 1 at CHAT013 [m—meter].

Type	Area (m^2)	Perimeter (m)	Hydraulic Radius (m)	Width (m)	Depth (m)	Width/Depth
Bankfull	2.11	9.30	0.23	8.87	0.55	16.12
Channel-full	16.43	14.23	1.15	12.71	1.90	6.69
Bankfull and Channel–full Ratio	7.77	1.53	5.08	1.43	3.45	0.42

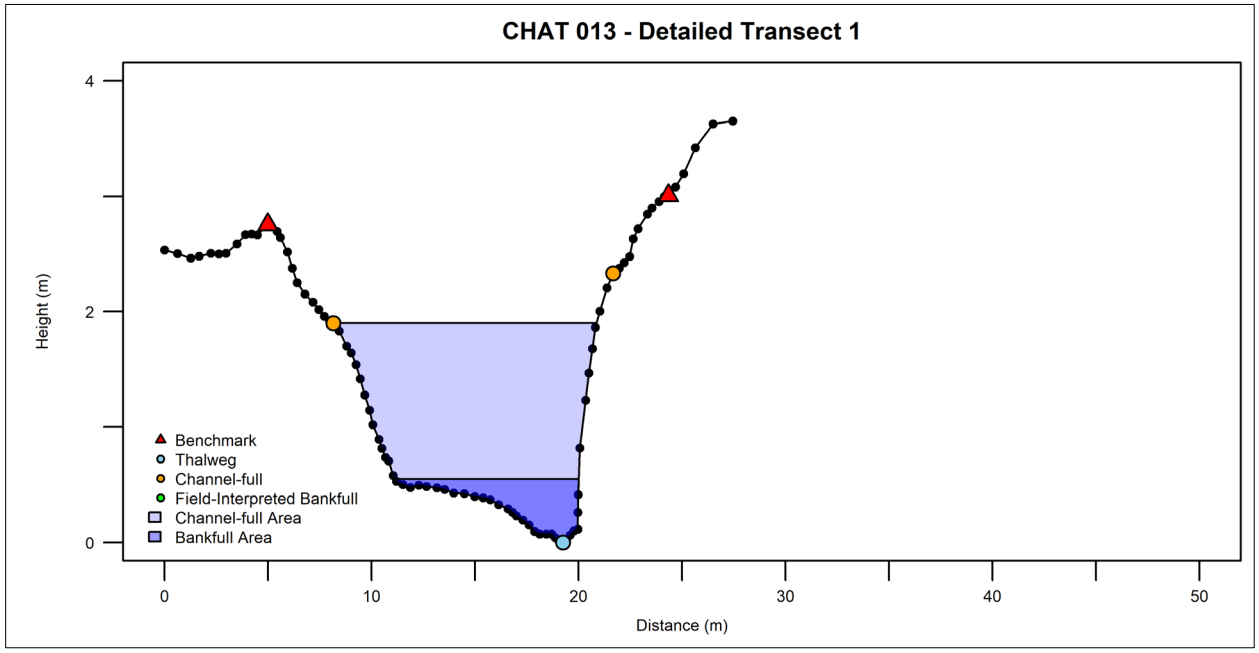


Figure O-14. Detailed transect 1 at CHAT013. The surveyed locations of the left and right benchmarks, channel-full bank-tops, and interpreted bankfull bank height are shown on the figure. Additionally, the channel-full (light blue) and bankfull (dark blue) cross-sectional areas are also included (channel-full cross-sectional area equals light blue plus dark blue).

Table O-7. Cross-sectional characteristics for detailed transect 2 at CHAT013 [m—meter].

Type	Area (m^2)	Perimeter (m)	Hydraulic Radius (m)	Width (m)	Depth (m)	Width/Depth
Bankfull	4.36	10.00	0.44	9.27	0.55	16.86
Channel-full	20.04	14.43	1.39	11.77	2.13	5.51
Bankfull and Channel–full Ratio	4.60	1.44	3.19	1.27	3.88	0.33

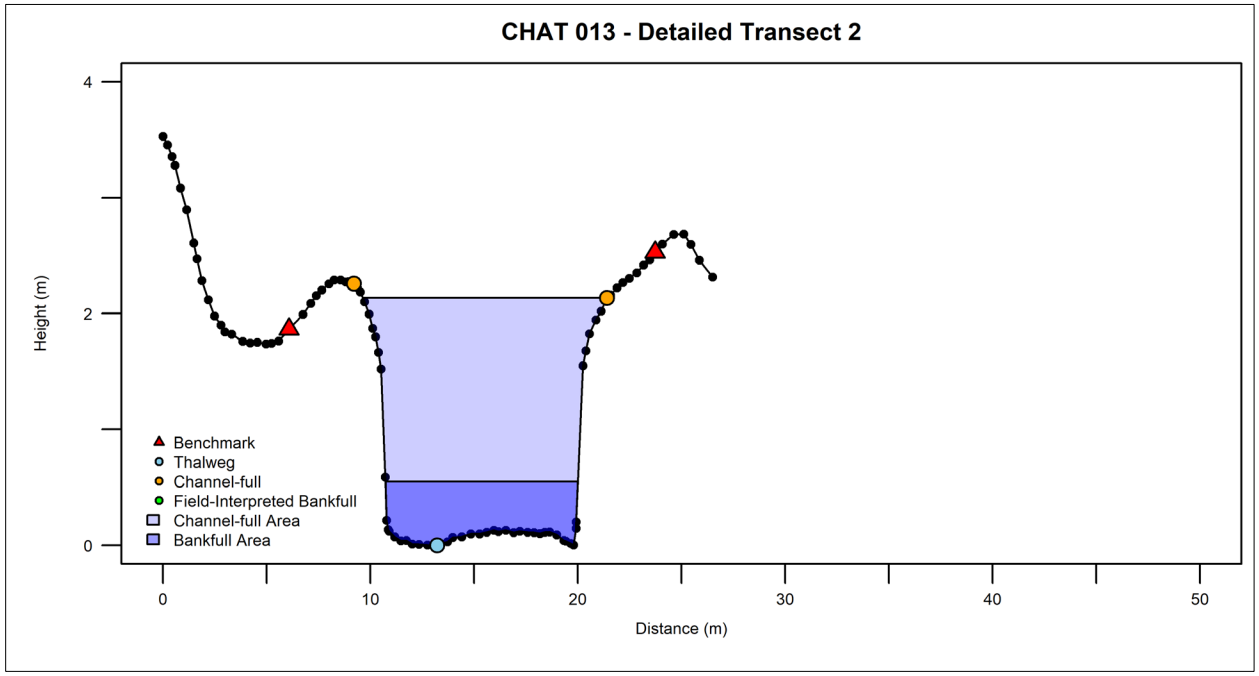


Figure O-15. Detailed transect 2 at CHAT013. The surveyed locations of the left and right benchmarks, channel-full bank-tops, and bankfull bank height are shown on the figure. Channel-full (light blue) and bankfull (dark blue) cross-sectional areas are also included (channel-full cross-sectional area equals light blue plus dark blue).

Table O-8. Cross-sectional characteristics for detailed transect 3 at CHAT013 [m—meter].

Type	Area (m^2)	Perimeter (m)	Hydraulic Radius (m)	Width (m)	Depth (m)	Width/Depth
Bankfull	8.76	16.42	0.53	16.05	0.80	20.01
Channel-full	42.32	27.37	1.55	25.68	2.22	11.54
Bankfull and Channel–full Ratio	4.83	1.67	2.90	1.60	2.77	0.58

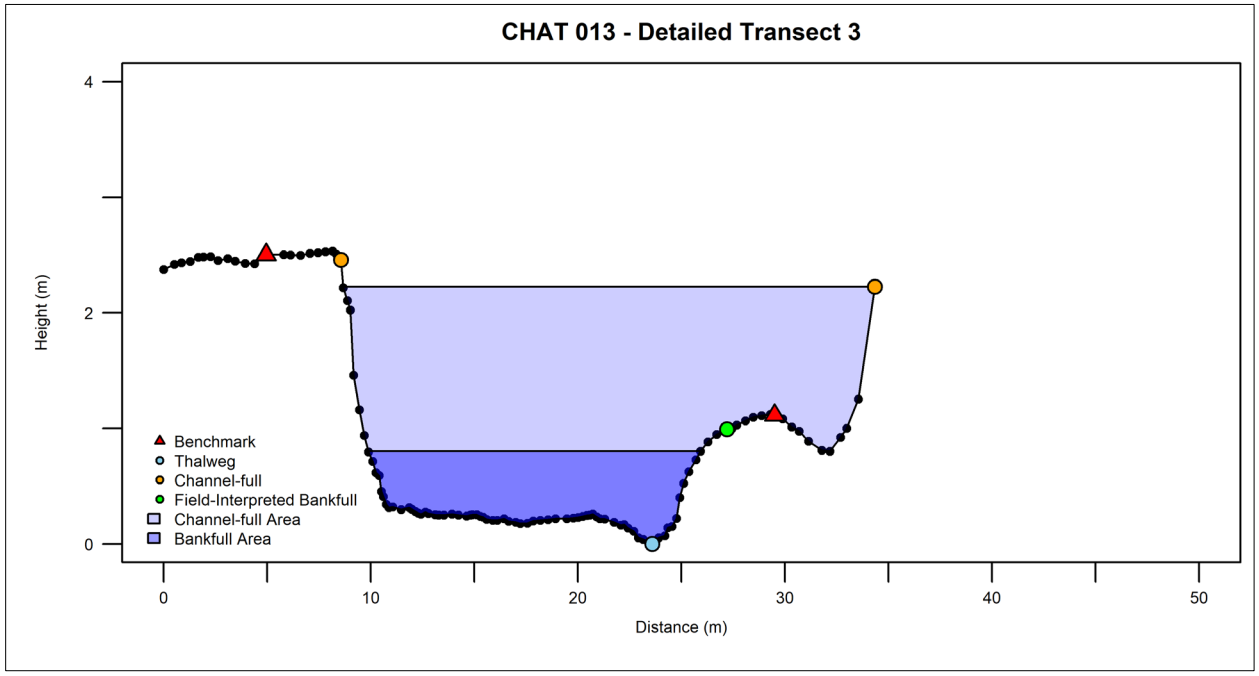


Figure O-16. Detailed transect 3 at CHAT013. The surveyed locations of the left and right benchmarks, channel-full bank-tops, and interpreted bankfull bank height are shown on the figure. Channel-full (light blue) and bankfull (dark blue) cross-sectional areas are also included (channel-full cross-sectional area equals light blue plus dark blue).

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Fry, J. A., G. Xian, S. Jin, J. A. Dewitz, C. G. Homer, L. Yang, C. A. Barnes, N. D. Herold, J. D. Wickham. 2006. Completion of the 2006 National Land Cover Database for the conterminous United States: Photogrammetric Engineering and Remote Sensing, v. 77, no. 9, p. 858–864.

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The Department of the Interior protects and manages the nation's natural resources and cultural heritage; provides scientific and other information about those resources; and honors its special responsibilities to American Indians, Alaska Natives, and affiliated Island Communities.

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